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THE
BRITISH JOURNAL OF SURGERY

INTRODUCTORY.

THE MEDICAL DEPARTMENT OF THE ROYAL NAVY.

IN the Royal Navy, where service in times of peace approximates so closely to the conditions in war, the organization of the Medical Department, in common with that of the other permanent branches, suffers no radical change when hostilities are declared. Such re-arrangements and extensions as occur have been rehearsed to a degree sufficient to test all the machinery required for a rapid mobilization to full war strength. Beyond the redistribution of a limited number of active service medical ranks and ratings, the admission of reservists, temporary service auxiliaries, and volunteers, and the extension of hospital accommodation, there is no disturbance of existing arrangements. The same organization which augments the personnel for the grand manœuvres of peace time is employed on occasions of war. The Medical Service required for new units and new formations arising during the progress of hostilities, such as the battalions of the Royal Naval Division and the Armoured Car and other detachments serving ashore, is but an extension of that supplying the Royal Marines and the Royal Naval Air Service which is permanently under Admiralty control; while the arrangements for the transport of wounded are but expansions of the system of collecting naval invalids and hospital cases from ports and fleets by hospital ships, a system that has been in existence for many years. The provision of hospital trains for the distribution of wounded to the naval hospitals, and the appointment of medical transport officers to control this service, is practically the only part of the programme of transport that has not been rehearsed.

This easy transition from peace to war is in marked contrast to the violent dislocation and re-organization which of necessity attend the mobilization of large military expeditionary forces and the creation of huge armies from raw material. In the Navy, fortunately, the expansion, great as it is, has not proved overwhelming. The many hundreds of civil entries—surgeons, nursing-sisters, and sick-berth ratings—have been absorbed into its system

without upsetting the medical organization or diverting the regular medical staff from the duties for which they have been specially trained. In the naval hospitals, establishments, hospital ships, and in all large fighting ships, administration, responsibility for the care and attention of the sick and wounded, together with the greater part of the practical work—surgical, medical, bacteriological, etc.—remains under the immediate care of the regular medical officers. Fortunately, indeed: because, however skilled and capable a civilian may be, it takes many years of close association with the Navy to acquire that intimate knowledge of the Service and to develop to the fullest value those qualities required to mould the man to fill his part in that complex machine the modern battleship, or to perform with efficiency his share of the administrative work of a naval hospital.

To deal adequately with the surgical organization in the present naval war it would be necessary to describe the normal organization in more detail than space permits. It must suffice to limit the review to a consideration of certain special features, and to the focal point of interest—the naval surgeon himself, his general efficiency, and his ability to apply the resources of modern surgery to the benefit of the wounded sailor at the time of injury and after.

As a Health Officer of the Navy, the Surgeon—to give him his official title—has stood the test. Year by year the sick rate has steadily decreased. In this, the third year of war, the ratio in the Grand Fleet is but little more than one per cent. Many factors have combined to produce this immunity from sickness. The share of the medical officer in the achievement is not to be overlooked. One is tempted to dilate upon so important a subject, and to contrast the present with past occasions of war which have kept large fleets in being; but in a journal devoted to surgery matters of hygiene are of subsidiary interest.

The Navy is proverbially a silent Service. The reticence of the medical branch accounts, perhaps, for the ignorance of the public concerning the naval medical officer, his duties, his opportunities, and his aspirations. With the exception of some admirable work in the study of tropical diseases, he is rarely to be found as a contributor in the pages of professional literature. Until the birth of the *Journal of the Royal Naval Medical Service* some two years ago, his written word has lain buried in official records and reports. It is no exaggeration to say that in the popular fancy he is still the 'cockpit' surgeon of Smollett's novels, rough, and over-ready to probe a wound or amputate a limb. That he should have opportunities for practising any but 'cockpit' surgery is unimagined by the general public. The humour of *Punch's* illustration of a sailor mildly expostulating that the surgeon has dragged him round the sick-bay with the dental forceps attached to his tongue instead of to his tooth, lies in the indulgent acceptance, by the patient and the public, of the operator's limitations.

We are often reminded that the lay medical profession is not more enlightened than the general public concerning the Naval Medical Service. Of some six hundred and fifty young men who, at their country's call, have joined the Navy as temporary surgeons, few had any conception of the nature of the Service they were entering. A medical officer of a fighting-ship was to them but a glorified variant of the 'qualified surgeon' of the passenger ship's advertisements. They learned with surprise that they were not to be drafted at once for service afloat. They found themselves appointed temporarily to one of several huge naval hospitals—institutions hitherto unheard of by them. They were to learn that these establishments are complete in every up-to-date detail; that in the several departments, medical, surgical, *x*-ray, bacteriological, venereal, zymotic, etc., the work is carried on, and for years has been carried on, with that eager aim to obtain the highest efficiency which is traditional in the Naval Service. They were to learn that these departments are staffed and administered by naval surgeons who, with the exception of those of the higher ranks, are taking their turn at hospital work after a recent term of service afloat.

Here, in these self-contained hospitals naval surgeons perform daily many surgical operations. A total of nearly 5000 operations—exclusive of dental operations and salvarsan intravenous injections—were placed to the credit of the naval hospitals during the last year of peace, and all were performed by naval surgeons who had acquired their operative experience and skill while in the Service. Since the beginning of the war the number of operations has greatly increased.* The surgical work has been assisted by the consultant surgeons who have supplemented the senior ranks, and by temporary surgeons who have relieved many of the junior operators.

It may appear surprising that in peace time there should be such a large amount of surgical material in a service composed of picked men, the majority in the prime of life. It is to be noted that this material is drawn not only from the Service afloat, but also from the large naval establishments ashore, such as the Royal dockyards—where many thousands of workmen are employed in shipbuilding, etc.—from training schools, and, to a limited extent, from

---

* During the year 1916 over 9000 surgical operations (exclusive of dental operations and intravenous injections) have been performed in the naval hospitals and hospital ships. Of this number over 800 were abdominal cases, including 627 cases of appendicitis and 55 of gastric or intestinal perforation. Operations for the relief of disabilities were numerous. Hernia is represented by 1341 cases. Less common operations are mastoidectomy (89 cases); operations on the nose and eye; on the kidneys, bladder, and prostate; and on the liver, gall-bladder, and gall-ducts. Many cases of bone plating and wiring are recorded. Spinal analgesia has been employed on several occasions, and local anæsthesia is becoming more frequently used for rib resections, varicose veins, etc.

among pensioners and officers on the retired list. From these sources a wide surgical practice is obtained in the treatment of diseases and injuries arising in males after the age of thirteen years. The addition to the Navy of many thousands of auxiliaries of a lower physical standard than the active service ratings has extended the variety of diseases coming under surgical treatment.

It has been the aim of the Administration to give a period of hospital experience to as many medical officers of the fleet as circumstances permit. By this means a large and increasing proportion become well practised in modern methods, and not a few develop surgical skill of a high order. Consequently, in every fleet are to be found officers thoroughly capable of meeting all surgical requirements.

The growth of surgical efficiency in the Navy has been very marked during the past twelve or fifteen years. Up to that time major surgical operations were rarely undertaken. There was a great loss to the Service of men invalided for such disabilities as hernia, varicose veins, etc. Coincident with the more general employment of surgical means elsewhere, the spirit of surgical enterprise arose in the naval hospitals. It did not originate, as might be supposed, from the influx of new blood, or from suggestions by the Administration. It arose from the enterprise of a few pioneers, men of several years' seniority, who, developing a latent ability, with courage and determination fought down prejudice, and laid the foundation for that confidence in the surgical work of our hospitals that is now shown by all ranks of the Service. This growth of efficiency was fostered by the Administration. The hospitals were provided with every surgical necessity. Old operating rooms were re-constructed and new rooms added. *X*-ray departments were instituted. The new hospital at Chatham, built during this period, was furnished with the latest surgical apparatus. Officers were selected and appointed to all the large hospitals as anæsthetists and radiographers. As many medical officers as arrangements permitted received post-graduate courses at recognized schools. These courses included special instruction in operative surgery. Selected sick-berth ratings were trained as operating-room attendants. No difficulty was found in obtaining a succession of senior medical officers capable of taking up the surgical work. There seems to be no doubt that a close association with the strenuous activity that exists in the fighting branch of the Navy develops the qualities of handiness and adaptability. In such practical subjects as surgery, radiography, and bacteriology, the seasoned naval medical officer quickly becomes efficient.

While the practice of surgery was being encouraged in the hospitals by the provision of all requirements, the surgical equipment of the ships was greatly improved. Special stations for the treatment of wounded during action were considered in the design of the vessels, and not left to be

extemporized as had been the custom. These stations were fitted with a supply of hot and cold water, special ventilation, lighting, and equipment generally. Formerly the surgeon had to provide himself, at his own expense, with a regulation set of surgical instruments, a stomach pump, splints, and a few other necessary articles. For some years past all the larger ships have been supplied by the Admiralty with a liberal outfit of instruments, including microscopes, and sterilizing, *x*-ray, and bacteriological apparatus; recently a medical library of reference has been added. These stores are supplied from the naval hospitals, where they are kept ready packed to be issued at a moment's notice.

In addition to being hospitals proper, and centres for distribution of stores, these establishments are training-schools for the sick-berth ratings. In peace time, courses of lectures are given by the staff to medical officers attached to or in the vicinity of the port. For over thirty years the Royal Naval Hospital at Haslar has been a training centre for newly entered surgeons. Within recent years the newly entered have been required to pass an examination at the end of a period of probation before receiving their commissions. During the war all regular courses of instruction at Haslar and Greenwich have been suspended.

At the outbreak of hostilities, fighting-ships in commission, and those newly commissioned, received their war complement of medical officers, sick-berth ratings, and medical stores. The hospitals were brought up to their full war accommodation and staff, and the pre-arranged scheme for overflow to the subsidiary naval infirmaries and temporary hospitals was put into force. This scheme has been considerably expanded, especially in Scotland, to meet the growing necessities of the fleet. Hospital ships have been equipped and staffed. Private yachts, fitted out by their owners, have been taken over by the Admiralty as hospital ships for the transport of the sick and wounded over short distances. A great deal of surgical work has been undertaken in hospital ships, both while acting as mobile base hospitals to the fleets, and while carrying naval and military wounded. A share of this operative work has been borne by temporary surgeons. The employment of hospital ships as mobile base hospitals enables the fleet to use suitable bases without regard to considerations as to the disposal of the sick and wounded; and as these bases or rendezvous may be a considerable distance from the naval establishments ashore, the transport of the acutely sick and wounded is reduced to a minimum. During the military operations in the Gallipoli Peninsula, naval hospital ships in the Mediterranean were employed chiefly in receiving the wounded direct from the dressing stations and transporting them to base hospitals in Egypt, Malta, and elsewhere. Although the number of casualties coming under treatment after naval actions afloat have been comparatively few, the naval home hospitals

have been very full at times, since accommodation has been given to our own and Belgian military, as well as to the sick and wounded from the battalions of the Naval Division fighting ashore. In addition to the arrangements made for overflow to subsidiary hospitals in the vicinity of the ports, provision was made for the reception of cases in some of the London hospitals.

Afloat, the organization for the immediate treatment of the wounded varies with the class of fighting-ship. In all ships the sick-berth is situated in too exposed a position to be used during action. Two main stations are selected, one forward and the other aft, in the best protected and most accessible situations. Here the wounded are brought by collecting stretcher-parties during pauses in the fighting. After treatment they are passed on by distributing stretcher-parties to disposal stations. Many of the cases receive first-aid treatment at the hands of their comrades before they arrive at the receiving stations, for in all turrets and isolated positions dressings, tourniquets, etc., are provided.

The experiences gained in the present war have proved the value of the instruction in first aid given to the ship's company; this is especially noted in unarmoured ships, where it is practically impossible for the wounded to be collected or for the surgeon to reach the wounded during action. In the work of attending the injured the surgeons and staff are assisted by officers and men of the non-combatant branches. All details of this organization are rehearsed frequently in a realistic manner. Of the many forms of apparatus for removing wounded from difficult places, the Neil-Robertson stretcher has proved most suitable.

Before going into action, the men are required to change into clean clothing in order to lessen the liability to septic infection. Sepsis from the presence of virulent micro-organisms rarely occurs afloat. This freedom has permitted the complete closure of severe shell wounds to be made after excision of damaged tissues, with results that are most encouraging. The large proportion of burns on uncovered parts of the body have called for special measures for the protection of the face and hands. The treatment of burns by recent and improved methods is receiving careful attention.

Scientific investigations have been made in the laboratories of the hospitals as to the relative bactericidal power and tissue penetration of various antiseptics; and the practical value of the Dakin treatment of wounds has been the subject of a special commission of experts. In this experimental work, as well as in surgery, medicine, bacteriology, and anæsthetics, the regular medical officers have received the greatest assistance from consultants and temporary surgeons. The services of the probationary surgeons—i.e., advanced students, not yet qualified, engaged during the war—must not pass unnoticed. These young men, in medical charge of scouts, destroyers,

and other small craft, have accepted the responsibilities and the risks of their dangerous employment with courage and devotion to duty.

When peace is restored and stock is taken of our professional experiences, we shall realize to the full how greatly the Naval Medical Service has benefited by the close association of its members with representatives of all grades of civilian fellow-workers. We may anticipate with confidence that not the least of the advantages arising from this comradeship will prove to be a more general appreciation of the wide variety of practice, the certain recognition of merit, and the many opportunities for professional advancement, that are offered with a surgeon's commission in the Royal Navy.

ARTHUR W. MAY.

JOHN BANESTER.

1533–1610.

THE commemorative picture which shows John Banester lecturing on anatomy gives several interesting details about him. There is in the first place the record of his age, 48 in the year 1581. He was born, therefore, in 1533. Secondly his armorial bearings, with the appropriate cadency sign, showing that he used the coat armour* of the Banisters of Cobham, and that he was the second son. It follows that he was the second son of John Banister of Cobham, who was one of the Barons of the Exchequer. His books are dated, however, from Nottingham, where he lived for some years. He had relatives there, for the Chamberlain's accounts for the year 1573 record: "Item, given the same day [July 17, 1573] a pottell of wyne and halfe a lb of seugar unto Maister Banyster the Preacher." He may also have had a connection with the Barbers' Company, for a John Banister appears seventy-ninth on the list of members of this Company in 1537.

The first fact now known about him was that he acted as Surgeon to the Forces sent to relieve Havre under the Earl of Warwick in 1563. Here he probably formed a life-long friendship with William Clowes, who speaks of him as "Master John Banester, my dear and loving friend"—a friendship which led Clowes to introduce each of Banester's works with commendatory verses, and to write a long epitaph in verse, which was destroyed when St. Olave's, Silver Street, was burnt in the Great Fire of London.

In 1572 Banister was admitted a member of the Barber Surgeons' Company, and there is a note still extant in the records saying that "Mr. Banester of Nottingham was sworn and admitted a brother of this mystery. Whereupon he hath granted to the House yearly twenty shillings so long as he liveth and to be liberal and commodious to this house in that he may, and will yearly send a buck or two and hath paid ten shillings and shall have his letter of licence." The note is as remarkable as it is unusual. The friendship of Clowes, or Banister's own family interest, may have gained him admission to the Company—for it is evident that he was never apprenticed—but it was not everyone living in the reign of Elizabeth or in the neighbourhood of Sherwood Forest who could promise to send a buck or two yearly so long as they lived. It is clear, therefore, that he had considerable influence.

In 1573 the University of Oxford granted him a licence to practise physic. The record runs: "Banister John after seven years in medicine supplicates for a licence to practise medicine 30th June 1573." He thus acted both as a physician and as a surgeon, a most unusual combination at a time when the surgeons were still held in thraldom by the physicians.

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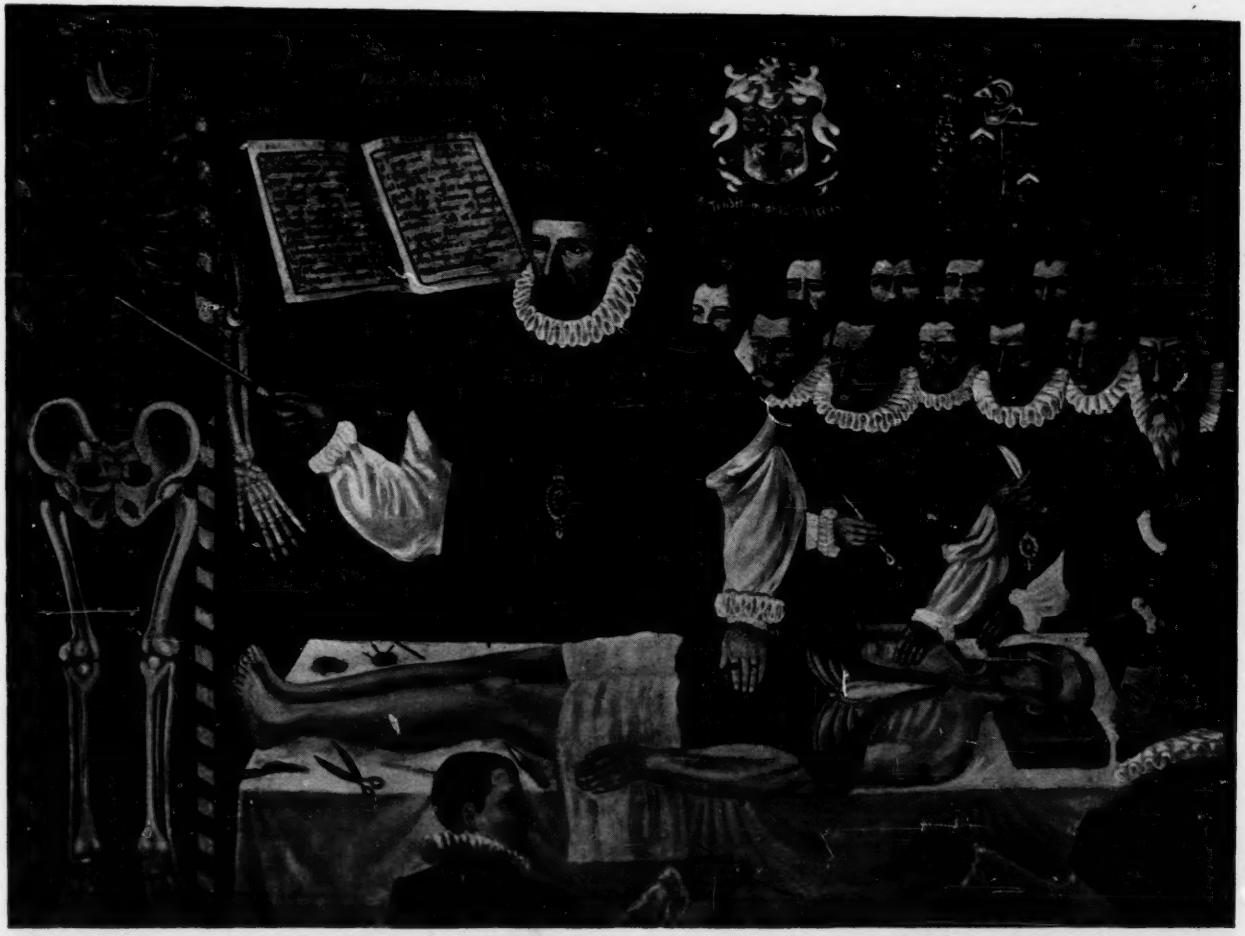
* Argent, a cross fleury sable. Crest: a peacock sitting, taking in its beak a serpent twined proper round its neck, all proper.



JOHN BANESTER DELIVERING THE VISCERAL LECTURE AT THE BARBER SURGEONS' HALL, LONDON, IN 1581.

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In 1581 he lectured at the Barber Surgeons' Hall in Monkwell Street, his predecessor being Thomas Hall, the son of John Hall of Maidstone, who was appointed in 1577. In 1585 he served on board ship during the Earl of Leicester's expedition to the Low Countries, and on February 15, 1593–4 he was licensed to practise medicine by the Royal College of Physicians of London, in obedience to a letter signed by Elizabeth, " given under our signet at our manor of Otelands, the xxviiith day of July in the xxxvth year of our reigne." The reason assigned by the Queen for desiring this favour was that " he desireth to end his old yeares in quietness, as I trust he shall do unless he happened to be molested by any of your College." The College dared not disobey the request, repugnant as it must have been, since Banester was a surgeon. They granted it, but added the condition that " in omni graviori morbo et pleno periculi unum aliquem ex Societate Collegii ut adjutorem sibi in illa curatione accersat et adjungat (in every serious and dangerous case he must call in some one else belonging to the College). In 1578 he was living at Nottingham ; in 1585 he had moved to London, and lived in Silver Street, where he died in 1610; he was buried in St. Olave's Church in the same street.

Banester wrote : (i). *A needefull, new and necessarie treatise of Chirurgerie, briefly comprehending the general and particular curation of Ulcers taken foorth of sundrie worthy wryters, but especially of Antonius Calmetus Vergesatus and Joannes Tagaltius. Imprinted at London by Thomas Marshe, Anno* 1575. The work is a duodecimo, dedicated to " the Right Worshipfull maister Thomas Stanhope Esquire and high sherife of Nottinghamshire this present yeare of oure Lorde 1575." Following the epistle dedicatory are twenty-five stanzas of verse by the author in praise of " Physicke and Chyrurgerie," which is again followed by an epistle dedicatory to " the Worshipfull Maister, Wardens and generall assistauntes of the fraternity of Chyrurgians in London," and dated from " my house in Nottingham the vi of June 1575." The consideration of the degraded state of surgery again moves him to verse, and he apostrophizes " evil and counterfeit dealers in the art of Physic and Chirurgerie." This apostrophe is followed by commendatory verses by Richard Smith and William Clowes, George Baker, and others, who as surgeons write in praise of the author. The book itself is of no interest. It is a mere dull compilation, without the illustrative cases which enliven the pages of Clowes and Gale.

(ii). In 1578 Banester issued in folio *The Historie of Man sucked from the sappe of the most approved Anathomistes, in this present age compiled in most compendious fourme and now published in English for the utilitie of all godly chirurgians within this Realme.* It was printed by John Day. The plates are copied from Vesalius. They have been re-drawn, reduced in size, and the backgrounds altered. As an anatomist Banester prefers Columbus, a point which he has had emphasized in his picture, where he chose to be represented in the act of lecturing from a passage in this author. The introductory verses are again by Clowes. The book itself is without interest.

(iii). *A Compendious Chyrurgie gathered and translated especially out of Wecker at the request of certaine . . . published for the benefit of all his countreymen by Iohn Banister Master in Chyrurgerie.* The book is a duodecimo " Imprinted by Jon Windet for T. Man and W. Brome." It is

dated "the xxvii of October from mine house in Silver Street." In moving to London it may be noted that the author had changed the spelling of his name from Banester to Banister. The book, like the other two, is uninteresting, except for a short series of four-line stanzas addressed respectively to the Reader, the Printer, and the Translator. The verse "to The Printer" may be given as an example:—

> Haste to the presse, feare not the sale,
> good wine doth neede no signe;
> The Surgeons craue this worke to haue;
> the gaine it will be thine.

A collected edition of Banister's works was published in 1633 in six books as a small quarto. The dedications and the text are left; but the poetry, having no doubt served its generation, has fallen on sleep.

It appears after reading Banister's books that he was never a surgeon in the sense that Clowes, Gale, and Barrough were surgeons. He occupied the position of a professor of surgery, and was the exponent of other men's views. He was a teacher rather than a practitioner of his art. As such, he would have no claim to notice in a journal of surgery; but he holds a definite place in the history of English surgery, because it is clear from his prefaces that he was heart and soul with those who, like Clowes and Gale in London, and Hall and Read in the provinces, made a determined attempt, during the reign of Elizabeth, to raise surgery from a trade to a profession. The attempt was made in several directions, partly by improving the examination for surgeons, partly by emancipating surgery from medicine, partly by demonstrating the ignorance of the quacks who then flourished so luxuriantly. But the time had not yet come, and their efforts ended in failure. The surgeons still remained subordinate to the physicians; the examination for admission to the Barber Surgeons' Company was nullified owing to the recommendations of unsuitable persons by powerful patrons, and the quacks continued to multiply in numbers and in influence. Banister either by his personality or by his influence held a higher social position than the other reformers. He alone was admitted to the College of Physicians, and he alone was granted a licence to practise by the University of Oxford. Yet his heart throughout was with Clowes and "The worshipfull the Maister Wardens and generall assistauntes of the fraternitie of Chyrurgians in London to whom John Banister (a member of the same) wisheth to them all, the true direction in the perfect way of knowledge to this misterious science according to their profession." He seems in fact to have lent to the movement the same sort of prestige that Pusey lent to the Tractarian movement. Like Hall, Clowes, and Gale, he hated quacks heartily, and addressed them in no measured language in the preface to his *Anatomy*: "As for you, O ye chaff of the earth, ye stinge of the Godly, ye impes of Hell and children of wrath, you (I say) that under the pretence of the sacred arte of medicine, devoure the sheepe of God's pasture, flea the labourers in his harvest and denye your Lord the fruits of the vineyard, since no warninges may admonish you, no exhortation amende you, no lawes bridle you, no punishements turne you, nor any feare of God sinke into youre brestes, I, from the depth of my hart renounce you, hopying

assuredly that from none of the flowers of this Garden any of you shall take opportunity to sucke that, which may maintaine the infection of your pestilent wretchedness hereafter." Indeed he gave his daughter Cicely in marriage to John Read, one of the foremost of the reformers, whose early death must have been a severe blow to the cause.

Clowes's epitaph, even allowing for exaggeration, seems to show Banister as a generous and humane practitioner :—

> Thy Skill and Practice, that itself commends
> Some of the best have truly found the same
> Not partially employed to wealthy Friends,
> But even the poorest Wretch, the Sick and Lame
> Felt of the best : some Difference there might be,
> The Rich paid somewhat, poore Men had it free.
> The Weekly Charity given to the Poore
> In Bread beside, in Money from thy Purse,
> Even in the hardest yeares dealt at the Doore.
> Poore maymed Souldiers, sore sick-hearted Men
> That under Miseries hard Crouch did bow,
> Were freely cured, methinkes they cry, Lord, when,
> Where shall we find our good Physician now ?

The original of the picture which is here reproduced is in a volume of 'Master John Banister's Anatomical Tables," in folio, which is in the Hunterian Library at Glasgow. The picture is double page, mounted on guards, and backed with modern white paper. It represents John Banister delivering the "visceral lecture" in the Barber Surgeons' Hall at Monkwell Street. The carefully painted figure in the Master's hat and the furred gown is probably the Master of the Company for the year 1581. If so, he is Robert Mudesley, to whom Thomas Vicary bequeathed "my best single gowne faced with black satten." He is also mentioned in the 1569 grant of arms as one of those governors of the Barber Surgeons' Company who petitioned for some permanent mark in their armorial bearings* to commemorate the union of the Barbers and Surgeons. The grant by letters patent took the form of "an augmentation in chief to their old and auncient arms with heaulme and crest to the same." It was perhaps for this reason that the painter has introduced the new coat of arms into the picture, containing a lion of England and two crowned Tudor roses.

The two senior stewards of anatomy are distinguished by their badges. It was enacted in 1555 that there should be chosen every year two "for the Anathomye and other two also to be chosen for to be stewards ; so that two always shall stande for ij yeres because they that doo not worke of the

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* The arms of the Barber Surgeons are those granted to the United Company by Sir Gilbert Dethick, Garter King at Arms, in 1569. They are : "Quarterly the first sables a cheveron betweene three Flewmes argent ; the seconde quarter per pale argent [and vert on a spatter of the first, a double Rose gules and argent crowned golde ; the third quarter as the seconde and the fourth as the first. Over all on a Crosse gules a lyon passant gardant golde ; And to their Creaste upon the heaulme on a Torce argent and sables an Opinacus golde ; Mantelled gules doubled argent ; Supported with two Linxe in their proper coulor about their neckes a crowne with a chayne argent pendent therat." The motto "De praescientia Dei," which is still used by the Company of Barbers, now first appeared in the armorial bearings of the Barber Surgeons.

Anatomy the one yere being Stewards for the provysyon of victualls they shall worke the other yere following. And they that shalbe chosen shalbe alwayes for the first yere Stewards, because that they shall see the makynge of them the yere before that they may be the more practysed in the doynge the next yere the sayed Anathomye that after it maye appeare by the workmanship that they be the dooers. Yf the Master and governors do goo about to breake the same acte they shall lose for a fyne to the hall xls."

The class consists of the members of the Barber Surgeons' Company, who were obliged to attend the lectures under penalty of a fine.

The picture is interesting from many points of view, and first historically. It represents almost with the accuracy of a photograph the method of conducting anatomical teaching in London at the end of the sixteenth century, and, so far as is known, it is the only illustration of the lectures given at the Barber Surgeons' Hall. It furnishes additional facts about John Banister. It is clear that he was the Company's visceral lecturer in 1581, which was not previously known. The minute accuracy of the picture is shown by the vade mecum which is used as the text of the lecture, and it will be noticed that the skeleton is supported and crowned with the colours of the Barbers' Company, and a wreath of the same surmounts the helmet in Banister's arms. The book on the reading desk is "Realdus Columbus," and from its size it might be the folio edition printed at Venice in 1559. Reference shows, however, that the passage in this edition is on folios 227 and 228. The picture gives the pages 419 and 420. An octavo edition was published at Paris in 1572, and in Chapter 5 of Book xi the latter part of the passage quoted is found, just as the painter saw it, on pages 419 and 420. The minute detail is also shown in the drawing of the scissors, the different shapes of the dissecting knives, the double-headed retractor held by the steward of the anatomies, and by the Company's badges worn by the lecturer and stewards. Of the drawing from the artistic point of view it is less easy to speak. The two main figures of John Banister and the Master of the Company seem to be careful studies from life; the stewards and the audience are less carefully drawn. The body seems to have been drawn from the actual subject, who has a shrunken right leg—perhaps the result of old infantile paralysis—for the right foot is in a valgus position. The lecture is given on the passage: "Intestina igitur a ventriculo exoriuntur, eademq'; penè substantia videntur; licet aliquantulum tenuiore. Situs eorum est ab inferiori ventriculi orificio ad anum usque, abdominisq'; majorem partem occupant. Veteres Anatomici intestina in sex partes distinxere, distinctisque singulas nominibus appellauere. Ego verò si post tot seculorum recepta vocabula noui aliquid in medium proferre fas esset, intestina duo esse dicerem, quorum alterum tenue est, crassum alterum. Sed ut aliorum vestigia sequamur; (neque enim temere a veterum placitis discedendum est), sex esse dicemus intestina, duodenum, inquam, jejunum, ileon, coecum, colon, rectúmque."

Throughout the Middle Ages the surgeons of London were taught systematically and practically. The Barber Surgeons' Company, from its formation in 1540, organized a regular staff for the purpose, consisting of a Lecturer, who was sometimes a member of the Company but was more often a young physician fresh from Oxford or Cambridge, of four assistants, sometimes called

'Masters' and sometimes 'Stewards' of the Anatomies, and an audience consisting of the members of the Company. The subjects were obtained from the place of execution, and were four malefactors yearly. The lectures were three in number, the 'osteological,' the 'visceral,' and the 'muscular,' and great care was taken that they should be conducted decently and in order. They were public, or at least so public that any person could attend upon the introduction of a member of the Company, and they ended with a dinner, which was one of the most important annual functions of the corporation. The following extracts will give an idea of the conduct of the business :—

"The body having been brought to the Hall," it is ordered in 1567, "there shal be pyllars and rods of iron made to beare and drawe Courtaynes upon and aboute the frame where within the Anathomy doth lye, and is wrought upon, for bycause that no person or persons shall beholde the dissections of the body, but that all may be made cleane and covered with fayer clothes untyll the doctor shall come and take his place to read and declare upon the parts desected. And also yet fordermore that there shal be a case of weynscot made with paynter's worke upon it, as seemly as may be done for the skelleton to stand in."

Care was taken not only in choosing the lecturer, but his material comfort was provided for. It was enacted in 1555 that the stewards "which be appointed for the Anathomye for the year next following must sarve the Doctor and be about the body. They should see and provide that there be every yere a matte about the harthe in the hall that Mr. Doctor [be] made not to take colde upon his feete, nor other gentlemen that doo come and marke the Anatomye to learne knowledge. And further, that there be ij fyne white rodds appointed for the Doctor to touche the bodye when it shall please him, and a waxe candell to loke into the bodye, and that there shall be alwayes for the Doctor two aprons to be from the shoulder downwarde ; and two payre of Sleaves for his hole Arme with tapes for chaunge for the sayed Doctor, and not occupye one Aprone and one payr of Sleaves every day, which ys unseemly. And the Masters of the Anathomye that be about the bodye to have lyke aprones and sleaves every daye both white and cleane, yf that the Masters of the Anathomye that be about the Doctor do not see these thinges ordered and that their knyfes, probes and other instruments be fayer and cleane accordingly with Aprones and Sleves, if they doo lacke any of the said things afore rehersed he shall forfayte for a fyne to the hall xls."

It is to be remembered, too, that if fines were not paid, the Company had the power of summary committal to the Compter or even to Newgate.

The attendance at the lectures was compulsory. The ordinance of 1572 enacts that "every man of the company usinge the mystery or faculte of surgery, be he freman, fforeyne, or alian straunger shall come unto the Anathomye, being by the Beadle warned thereunto. And for not keepinge their houre both in the forenoone and also in the afternoone, and being a freman shall forfayt and paye at euery tyme iiijd. The fforeyn in like manner and the Straunger euerye tyme vjd. The said fynes and forfaytes to be employed unto the Anathomysts for the tyme beynge, towards theire charges within the tyme of the sayd Anathomye. And also for not comyng in all the tyme of the Anathomye (having lawful occasion of absence) the

Freeman shall pay vjd., the fforreygne vijd., and the Straunger xijd. And to be employed in manner and fourme aforesaid. And also iijs and iiijd. to the Masters and Gouernoures of the said Mystery for their summons brakinge notwithstanding. Provided also that they come well and decently appareyled for their own honestye, and also for the worshippe of the companye."

The following directions, which were evidently given by an old clerk of the Company to his successor new to the office, show how the business of a lecture was conducted. They are headed: "Form of the business at the time of a Public Demonstration of Anatomy."

"So soon as the body is brought in deliver out your ticketts, which must first be filled up as followeth—4 sorts: The first fforme to the Surgeons who have served the office of Master you must say, Be pleased to attend, etc., with which summons you send another for the demonstrations; to those below the Chaire you say, Our Masters desire your Company in your gown and Flatt Cap, &c., with the like notice for the Demonstrations as you send the Antient Master Surgeons. To the Barbers, if Ancient Masters, you say, Be pleased to attend in your Gound only; and if belowe the Chaire then, Our Masters desire, etc., as to the others above without the Tickett for the Demonstrations.

"The body being by the Masters of Anatomy prepared for the lecture (the Beadles having first given the Doctor notice who is to read, and taken orders from the Master or Upper Warden of the Surgeons' side concerning the same), you meet the whole Court of Assistance in the Hall Parlour, where every gentleman clothes himself, and then you proceed in form to the Theatre (vizt), the Beadles going first, next the Clerk, then the Doctor, after him the severall gentlemen of the Court. And having come therein, the Doctor and the rest of the Company being seated, the Clerk walks up to the Doctor and presents him with a wand and retires without the body of the Court until the lecture is over, when he then goes to the Doctor and takes the wand from him with directions when to give notice for the reading in the afternoon, which is usually at five precisely, and at One of the clock at noon, which he pronounces with a distinct and laudable voice by saying: 'This Lecture, Gentlemen, will be continued at Five of the clock precisely': having so said, he walks out before the Doctor, the rest of the Company following down [to] the Hall Parlour, where they all dine, the Doctor pulling off his own robes and putting on the Clerk's gownd first—which has been usuall for him to dine in—and after being plentifully regaled, they proceed as before untill the end of the third day, which being over (the Clerk having first given notice in the fforenoon that the lecture will be continued at Five of the clock precisely, at which time the same will be ended), he attends the Doctour in the Cloathing Room, where he presents him, folded up in a piece of paper, the sum of 10 li.;0;0, and where afterwards he waites on the Masters of Anatomy and presents each of them in like manner with the sum of 3 li.;0;0, which concludes the duty of the Clerk on this account.

"N.B.—The Demonstrator, by order of the Court of Assistants, is allowed to read to his pupills after the Publick Lecture is over for three days and untill Six of the clock on each day, and no longer, after which the remains of the body is decently interred at the expense of the Masters of Anatomy, which usually amounts unto the sum of 3;7;5."

A STUDY OF THE INTER-RELATION BETWEEN THE RADIOGRAPHY AND SURGERY OF GUNSHOT WOUNDS OF THE HEAD.

By Captain H. E. GAMLEN, R.A.M.C. and Captain S. SMITH, R.A.M.C.

At this General Hospital we have a record of at least 1500 radiographs of gunshot wounds of the head taken during the past eighteen months, a large proportion of them involving the skull and underlying brain. Thus we can lay claim to a considerable experience in the taking and interpretation of such radiographs.

Apart from the clinical picture, the factors which influence us when the question of operative interference comes to be discussed are: (1) The local condition of the wound; (2) The *x*-ray appearance. In deciding upon the value of the second factor, it is important that the surgeon and the radiographer should work in harmony, each surgeon examining the radiographs of his own cases and discussing them with the radiographer; for no surgeon without considerable experience in this work can interpret his own plates without help from the expert. A dried articulated skull is of great assistance in forming a good mental picture of the anatomy of the lesion; and just prior to the operation the radiographs should again be inspected, so as to revive the picture clearly in the memory of the operator.

We have divided our paper broadly into three sections:—

1. *The Method employed in taking the Radiograph*, discussing fully our technique where it has seemed to differ from that in common use.

2. *The Interpretation of the Radiograph.*

3. *A Classification of the Type of Injuries Revealed by the Radiographs*, and a discussion of the surgical practice adopted for each type.

I. METHOD OF TAKING THE RADIOGRAPHS.

We would at the outset insist that stereoscopic views should be taken in every case, being firmly convinced of the paramount importance of this method, which enables one as it were to look right into the patient's head, and to view in relief the injury to the various strata as it really exists.*

In radiographing these cases of head injury as we get them, comparatively soon after the infliction of the wound, special difficulties present themselves. The patients are often in a peculiar mental state, maybe restless or delirious. Consequently it may be necessary in certain of the cases to give an anæsthetic to ensure a reliable result. Short of this, rapid work with

* The illustrations in this article are printed each from a single plate of a stereoscopic pair, and consequently fail to show the depth of strata which is essential for the surgeon.

intensifying screens, necessitating an exposure of only a few seconds, may overcome the difficulty. The majority of slightly restless patients can be kept still, however, for the ordinary exposure of twenty seconds, with a compression cylinder, by making use of a paper air-cushion wedged between the head and the compressor.

The size of the plate, position taken, condition of the tube, number of milliampère-seconds given, and distance of the plate from the anode, are tabulated. Careful notes are also made on the final treatment of the plate, whether it is normally, under-, or over-exposed, and whether correctly, under-, or over-developed. Finally, the radiographer's diagnosis is added. These reports are standards for future work. Reduced stereoscopic slides are sometimes made, which often give a clearer and more instructive view with the hand stereoscope than the original negatives, because in reproduction any fault in density may be overcome.

Technique Employed.—As a preliminary, a small lead wire ring is placed over the wound surface, a clean new ring being used for each case.

At the outset it is necessary to decide in what position it is best for the head to be fixed for any given wound. In addition, the relation of a retained missile to the wound of entry, and the probable direction of any brain track, should be known. If time allows, therefore, a preliminary screening should be done, in order to give some idea of the position of the missile, which can generally be quite easily seen. Only in exceptional cases can one by screening follow the line of fractures, although if there be a large bone defect it can often be seen, as can also the track made by a large foreign body.

The wound surface should always be that nearest to the plate, with the area immediately surrounding the wound actually in contact with it, since in viewing the stereoscopic radiographs afterwards, the best results are obtained by viewing through the healthy on to the injured side.

If the wound and the position of the missile as viewed through the screen lead one to believe there is a track running in any given direction, experience has shown that the most satisfactory results are obtained by radiographing this track at an angle.

It is evident that the knowledge gained by screening, of the best possible route, and of the line of least resistance to the rays in various parts of the skull, greatly facilitates the work. Thus, in taking lateral views, we always endeavour to centre our rays through the squamous temporal, as offering less resistance than the thicker regions of the skull.

The condition of the tube, and the exposure, have often to be altered to suit the particular view which is to be taken. A lateral view, for instance, requires different conditions from an anteroposterior view in order to obtain the best results.

Of necessity the supine position is that selected for the majority of our cases, as few of them are sufficiently recovered on arrival to allow of any other position. If he has a short neck, the patient may find some of the postures uncomfortable, but this difficulty can usually be overcome by allowing him to rest on his side with the plate-holder raised to a higher level than that usually employed, using wooden wedges where necessary.

When correctly adjusted, the head is fixed by means of paper air-cushions,

partly inflated, which are placed between the head and the compressor. These take a grip of the greater portion of the head facing the tube, and an extra push downwards of the compressor makes any movement impossible. The radiographs are usually taken with the head in the lateral position, centring just above the external auditory meatus. If, however, the injury is near the vertex (this embraces the very important class of sinus injuries described by Sargent and Holmes), the head is tilted so as to allow the vertex to be nearer the plate than the base ; and vice versa, if there be an injury in the neighbourhood of Reid's base line, the base is approximated to the plate.

Slight manipulation of the skull in its relation to the plate, with a view to bringing the injured area as near the central rays as possible, brings out many details not otherwise obtained. In certain special cases, the indications for which will be described later, radiographs of the cranium are taken in an anteroposterior direction, the face being placed on the plate and the rays passing directly through the skull from behind forwards ; central rays are then made to hit the back of the skull one and a half inches either above or below the inion.

The distance of the anode of the tube from the plate varies from 58 to 64 cm., and the diaphragm is cut down so that both radiographs (stereoscopic) are just contained in the circle of illumination. The tube shift is 6 cm. The length of exposure varies with the age of the individual, old people requiring a longer one than young. The breadth of the head has to be taken into account, but as a general rule 120 to 140 milliampère-seconds are sufficient for lateral views, with an addition of about 30 per cent for anteroposterior positions of the skull. Until recently we have always had a vacuum tube in circuit ; but lately we have replaced this by a mechanical rectifier, which successfully prevents any of the inverse current from entering into the *x*-ray tube. The best work is done with the tube in a condition of 6 to 7 Bauer, the development being carried on from 15 to 18 minutes. Plates thus taken will show the contour of the skull on both sides when viewed stereoscopically. The majority of the lines of shadows are cast by the side of the head which is nearer the plate, and can be increased or decreased at will by varying the distance of the tube from the skull. These shadows can still further be modified during the development of the radiographs.

Positions of the Head.—As a result of our experience and of many trials, we now always fix the patient's head in one of the seven positions about to be described. The position varies according to the situation of the wound. From our records we find that the majority of wounds of the cranium occur over the temporoparietal area (50 per cent), next in order come those over the frontal area (25 per cent), and finally those over the occipital area.

A. Lateral Views.—

Position 1.—Particularly adapted for showing injuries to the lateral aspect of the frontal bone, the temporal bone, and also the parietal bone except at the summit. Lateral view centred at the temporomaxillary joint at the level of Reid's base line.

On looking from the healthy to the wounded side, a good view of the whole of the lateral aspect of the frontal and parietal bones is obtained, except towards the summit, and the squamous temporal is also well seen. We can

trace the edges forming the boundaries of the lateral sinus from the torcular forward as far as about the middle of the petrous bone, where the sinus sinks below the dense shadow cast by this bone—though towards the anterior part the edges become indistinct owing to their overlapping. The whole of the grooving for the superior longitudinal sinus can be made out, most distinctly in the anterior frontal and posterior occipital regions. Lateral views of the orbital plates of the frontal bones are seen, and the pituitary fossa and clinoid processes are very distinct. If, as sometimes happens, the sphenoidal cells are large and occupy a great part of the body of the sphenoid, they show up well. In this position the two temporomaxillary joints overlap, and consequently an indistinct view of these is seen. Overlapping views of the rami of the inferior maxilla are also obtained.

Position 2.—Adapted for showing the posterior parietal, temporal, and occipital regions. Lateral view centred at the base of the mastoid.

A better view of the orbital plates of the frontal bone is obtained than in *Position* 1, since the overlapping is not so marked. The pituitary fossa and clinoid processes are still well seen. A good view is obtained of the petrous bone throughout the greater part of its length. The anterior part of the lateral sinus is also seen better than in *Position* 1. In looking through the uninjured to the injured side, we see less of the contour of the temporal, parietal, and occipital bones than in *Position* 1. A very good overlapping view is also obtained of the inferior maxilla, provided the mouth is open.

By centring at a slightly higher level, say the level of the upper attachment of the pinna, we obtain a view looking into the cavity of the cranium from above. By centring thus, a better view is obtained of the orbital plates and of that part of the squamous temporal above and in front of the apex of the petrous bone. The bony landmarks around the foramen magnum are well brought out by this view.

Position 3.—Specially adapted to show injury to, or in the neighbourhood of, the superior longitudinal sinus. If an injury is seen at or near the vertex, the head is tilted so as to allow the vertex to be nearer the plate than the base. This is done by placing an air-bag under the shoulder and neck, so that the mastoid is 1 to $1\frac{1}{2}$ inches above the plate, and the central line of the vertex considerably nearer it than occurs when the two methods previously described are adopted. The base line is centred as appears most convenient, depending on the position of the wound.

When looked at from the uninjured to the injured side, we obtain an excellent view of the whole of the inner aspects of the frontal and parietal bones, together with the greater part of the occipital bone. The bones which go to form the bed of the superior longitudinal sinus are also well seen, the position now described being especially adapted for fractures in this neighbourhood. Previously, when lateral views were the only ones taken, thus allowing the opposite parts of the skull to overlap, one often experienced great difficulty in reading the radiographs, especially when the bony injury crossed or was in the neighbourhood of the several sinuses; slight fractures with depression of the inner table have been mistaken for lacunæ, the markings of blood-vessels, or overlapping of ridges which go to form the sinus. It was soon found that these defects could be overcome by tilting the head in various

ways so as to prevent the overlapping of the opposite shadows, and now we experience no difficulty in revealing fractures over the superior longitudinal and lateral sinuses.

A good view of the posterior surface of the petrous bone is obtained on the injured side, and also of the under surface of the base of the skull.

On reversing the plates, we have a still better view of the bones forming the upper half of the cranium, but not so extensive a view of the base as seen from above. A good anterior view of one petrous bone, and both aspects of the other, are shown. The torcular and the occipital sinus are well seen. In the event of the radiograph being taken with the mouth open, we obtain a good view of the temporomaxillary joints, and both sides of the inferior maxilla are very clear except in the central line, where the shadows overlap at the chin.

Position 4.—Specially adapted to show injuries at the base of the skull, the posterior mastoid, the occipital bone, and the lateral sinus. Great care has to be taken with this position in order to obtain the results desired. The head is first placed flat on the plate-holder, and an air-cushion introduced under the vertex and so arranged that the front of the head is at a higher level than the back. The plate is pushed so that its lower end rests under the third or fourth cervical vertebra, with the mastoid process resting firmly on the plate. By centring exactly two inches above the external auditory meatus, the central rays will pass in just posterior to the petrous bone; 10 per cent increase of exposure over the normal is allowed for this view.

On looking through the healthy on to the injured side of the skull, we obtain a good view of the orbital plates and the lateral aspect of the frontal bone, and of most of the parietal bone. Provided the angle is correct, a perfect view of the temporal and occipital bones is given.

If we centre a little higher, the lateral sinus throughout most of its extent, and the region of the foramen magnum, with the first and second cervical vertebræ, are added to the above view.

On reversing the plates, the base of the skull as seen from the underside is very distinct. With the mouth open, a good view of the inferior maxilla and of both temporomaxillary joints is obtained. This is the most suitable view for dental surgery, as there is no overlapping of the structures of the mouth.

B. Anteroposterior Views.—

Anteroposterior views of the head and neck are particularly useful for localizing the position of foreign bodies in relation to the central line.

Difficulties have been experienced in the past in giving the exact position of a missile lying in or near the body of the sphenoid, the anterior portion of the foramen magnum, or the bodies of the first to the third cervical vertebræ. The results obtained by operations undertaken for the removal of missiles lying in any of these localities vary very greatly according to the exact position of the missile and the relative ease with which it can be approached and removed by the surgeon. Consequently great attention to detail is essential. In the first place, if the correct exposure for a lateral view is known, an addition of from 25 to 30 per cent, using a tube low in vacuum, will give the best results. The head also must be securely fixed and centred. If good lateral views have already been taken, there is no necessity to

screen; otherwise one always screens, with the tube below the couch, using a high milliampèrage and a diaphragm cut down to give a minimum opening.

Two particular difficulties that have to be overcome in these antero-posterior views are :—

1. The broad horizontal band of shadow cast by the petrous bone. It is essential that, by tilting the head in a vertical plane, this shadow be prevented from overlapping that cast by the missile, or the value of the resultant picture will be much diminished.

2. The shadow cast by the lower jaw. This difficulty can usually be overcome by opening the patient's mouth to its widest extent, and fixing it in this position by a piece of cork placed between the teeth.

Position 5.—The plate rests on the forehead, and lightly touches the nose, the chin being two inches above the plate.

In this view the shadows cast by the petrous bone pass across the level of the upper part of the orbit, and it is only structures or foreign bodies within the skull above the upper limit of this shadow that are distinctly seen. We obtain a fairly clear view of structures lying immediately beneath the skull, particularly the first to the third cervical vertebræ, the pharynx, maxillary antrum, etc. Foreign bodies in the face below the level of the orbit can also be well seen.

Position 6.—The plate rests on the chin and the tip of the nose, and the central rays strike the back of the cranium at a slightly higher level.

The dark shadow cast by the petrous bone now obliterates the lower part of the antrum, but leaves a full view of the forehead, orbits, and upper part of the antrum. The greater part of the temporal and sphenoidal bones are well seen. With the mouth widely opened, a good view is obtained of the anterior aspect of the occipital bone, the foramen magnum, and the first three cervical vertebræ.

Position 7.—The plate again rests on the chin, but is separated an inch from the tip of the nose. This position is obtained by means of an air-cushion, resting on the forehead, between it and the plate. The central rays pass through the back of the cranium at the inion or just above it. It is necessary to further increase the amount of exposure to obtain the best results.

In this view the shadow cast by the petrous bone has moved still further down the face, and now lies at the level of the teeth when the mouth is closed. Within the cranium there is an unobstructed view of the interior. Below the level of the skull a further view of the region around the foramen magnum is obtained. The frontal and sphenoidal sinuses and the ethmoidal cells are particularly well shown. A good view of the whole of the antrum, nose, and orbits is obtained.

II. INTERPRETATION OF RADIOGRAPHS.

All those who have written on gunshot wounds of the head in the present war seem to be unanimous as to the paramount importance of a good *x*-ray photograph being taken as a preliminary to any operative interference, unless there be specially urgent reasons for performing an emergency operation.

In many cases which have come down the line after having been already

operated on in front-line units, a radiograph taken at this base hospital has shown flakes of bone and shell fragments still remaining embedded in the brain, in quite accessible positions. Secondary operations have often been necessary; the trephine opening, often a small one, has had to be enlarged, and the fragments, commonly the centre of a foul-smelling abscess, have had to be removed. One need hardly say that the mortality is high where such secondary operations have been necessary. We conclude from our experience of many of these cases, that if a radiograph was taken at all at the front, it must have been only a flat negative. One cannot insist too strongly on the necessity of stereoscopic pictures being taken in every instance, and with the greatest possible amount of detail. In viewing these plates through the stereoscope, it is important to have some method by which the light can be regulated, either generally, or locally in part of the field, for often a fracture invisible with a bright light is brought into view with a dimmer illumination.

In certain cases the lobulations of the brain itself can be distinctly seen. Particular attention is drawn to the fact that when a layer of blood-clot lies over the cortex, such an area of injury is seen less distinctly than is the surrounding brain, which fact has proved of some diagnostic value.

Foreign Bodies.—

Method of Localization.—By the use of a pair of compasses and a scale, one can in a few seconds give the size and depth of a foreign body below the wound surface once good stereoscopic negatives have been obtained, thus doing away with much of the elaborate machinery which has come into such prominence during the present war. On each plate appears the shadow of a pair of cross-wires at right angles to one another and in close proximity to the plate. The tube is moved a known distance between the two exposures in a direction parallel to one of the cross-wires. This causes the shadow of any foreign body to shift along the line. By the use of a pair of compasses one measures the distance of the foreign body from the other wire in each case. The difference between the two measurements gives us the shift of the shadow. There is a simple geometric relation between the shift of the tube, the shift of the shadow, and the distance between the anti-cathode and the plate. The shadow shift having been measured, it requires only a moment's calculation by the use of a slide-rule to determine the depth of the missile.

In reading such radiographs stereoscopically, one has to make allowances when, say, a dense white object, such as a bullet or shell fragment, is viewed against other objects the groundwork of which is not of so dense a composition, such as bone or soft tissues. The denser object will always appear nearer the observer than it really is. But as this occurs again when the plates are transposed, the fallacy is repeated, and the error can easily be corrected by experience, as there are so many other detailed parts in the field which can be brought into alinement.

Alterations in Position.—Some radiograms show that the missile has travelled in a zigzag direction before becoming stationary; in one case we were able to show clearly three distinct tracks due to the missile having twice been deflected at an angle. But apart from the clear proof that missiles are occasionally deflected in their flight within the skull, there is another possibility that has been discussed by surgeons—namely, as to whether a retained

foreign body may suffer secondary displacement as the result of falling downwards under gravity. From the evidence gained by frequently re-radiographing heads with retained missiles, we have come to the conclusion that there is rarely a late movement of the missile through the brain. In one case, however, at the first examination a damaged area was found extending beyond the foreign body, and a later radiogram showed that the missile had now travelled a short distance beyond its original situation, having indeed dropped forward into the area of ploughed-up and softened brain that already lay in front of it. But this type of movement is quite a different matter from that of a missile travelling later by its own weight through healthy brain. We have had the opportunity of viewing several radiographs which were supposed to demonstrate free movement beyond the track of a missile, but we have failed to convince ourselves of this movement, as in all cases examined, the second radiograph was taken in a different position from the first. Unless there is exact reduplication of the position of the head in the radiographs, the altered position of the missile is difficult to prove.

Distinguishing Characteristics.—It is sometimes difficult to distinguish between pieces of shell and of lead, and also between these missiles and bone fragments turned on edge. Rifle bullets end on to the plate may be mistaken for shrapnel balls. The distinction between lead and shell-casing is important when the question of the use of the magnet for extraction purposes is considered, as the magnet has attraction for pieces of shell-casing and rifle bullets, but none for lead. Pieces of lead are generally distinguished from shell-casing by their difference in shape and whiter appearance. When pieces of lead penetrate the cranium, they nearly always shed fragments in the brain track, and these are easily recognized by their white glistening appearance against the darker background (*Fig.* 7).

Pineal Body.—The shadow cast by the pineal body may easily be mistaken for a bone fragment. On several occasions while examining radiographs for lesions, we were puzzled by the presence of a small circumscribed area of density, generally oval in shape, and closely resembling a small flake of bone. Its position was constant, being situated mid-way along a line drawn between two points above and behind the two external auditory meati. To decide the nature of this small body, lead cyphers were fixed to the scalp two inches above the nasion and one inch above the inion. The object lay just above the line joining these two points, and about mid-way along it. Nasion to inion equals 20 cm.; the body was found 11 cm. from the nasion. This is the actual position of the pineal body in the middle line of the skull (from its position Lieutenant-Colonel Gordon Holmes assumed it to be the pineal body). In certain cases where a fracture exists, the presence of this small organ has complicated the diagnosis. We have already collected ten radiographs showing the presence of the pineal body, its visibility being doubtless due to the accumulation of opaque concretions that are liable to form in this organ after adolescence (*Fig.* 1).

Diagnosis of Fractures.—The dark shadow cast by a wound of the scalp, especially when there is considerable loss of tissue, is sometimes mistaken for a fracture; and the lighter markings due to the obstruction caused to the rays by some dressings, especially cyanide gauze, have to be kept in mind.

Sutures.—A fracture in the situation of the sutures may be overlooked, especially if it is small, and running in the same direction. In these instances radiographs should be taken so that there is no overlapping of the corresponding sutures on the two lateral aspects of the skull, and they should give the fullest possible detail.

Doubtful markings in the position of the Wormian bones present difficulties.

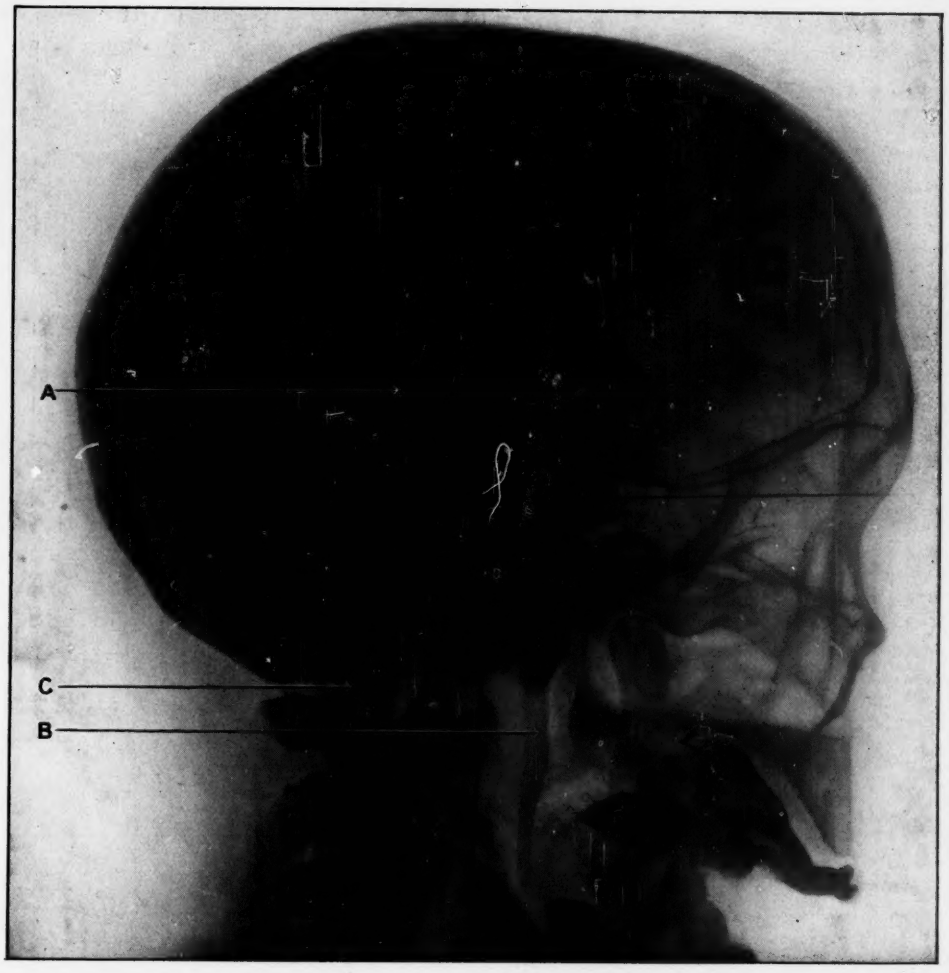

FIG. 1.—*Position* 4. Ring on scalp wound; no fracture, and no cranial injury. A. Pineal body, well-marked, opaque, and resembling a foreign body; B. Styloid process and stylohyoid ligament well-marked; C. One condyloid process of occipital is fairly seen.

Fractures in the line of the sagittal suture cannot be always diagnosed if an ordinary lateral view is taken. The shadows of the ridges which go to form the bed of the superior longitudinal sinus overlap, and it is only by taking radiographs in *Position* 3 that they can be separated so as to bring clearly into view the line of the suture.

The lambdoid suture along its whole length requires the minutest inspection to eliminate the possibility of fracture. In the position of the posterior superior and the posterior inferior parietal angles it presents difficulties which sometimes can be only overcome by radiographing in *Position* 4.

Minute fractures in the neighbourhood of the lateral sinus, especially beneath the petrous bone, are liable to be overlooked. Fractures in the

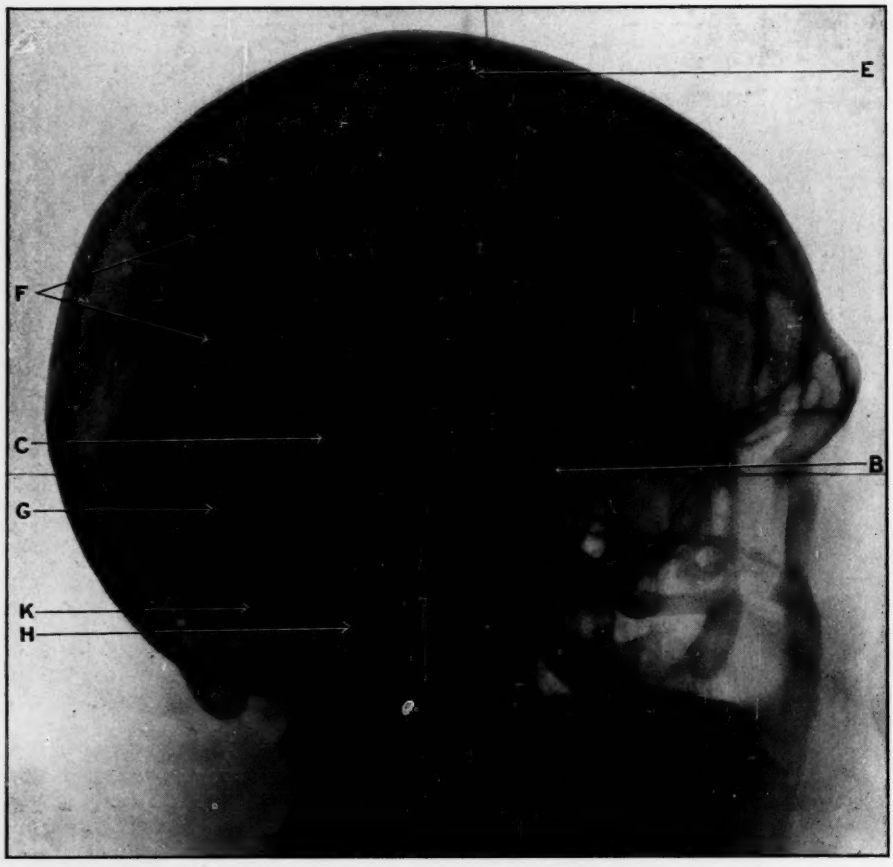

FIG. 2.—*Position* 4. Showing the posterior vascular sinuses. Depressed fracture; no penetration of dura. Ring marks the scalp wound, from the posterior extremity of which runs downwards and forward a wavy depressed fracture as far as the anterior missile B. It then passes downward and backward, where it terminates at the lambdoid suture C. Missiles are embedded in the bones. E. Well-marked lacunæ; F. Longitudinal sinus, which is seen passing backward and downward to the torcular G., and then outward and finally inward beneath the petrous bone to its termination H. The occipital sinus lies between G and H; H. Foramen magnum.

position of the torcular are easily diagnosed, provided they are taken in *Position* 4 or 5.

It is necessary to draw particular attention to a triangular shadow cast by the tip of the lesser wing of the sphenoid passing upwards and backwards, slightly in front of and parallel to the groove formed in the bone by the middle meningeal artery, as it is often overlapped by the one cast by the

middle meningeal artery where it grooves the anterior and inferior parietal We sometimes have found difficulty in giving a definite diagnosis in this situation.

Blood-Vessels.—In a large number of radiographs the shadows cast by the diploic, meningeal, and other blood-vessels of the brain are clearly shown, and in some cases difficulties have been found in distinguishing them from fractures. We have to take into consideration their length, shape, branchings, their thinning as they travel upwards to the vertex, and their presence on the opposite side of the cranium when the plates are viewed reversed.

Lacunæ due to thinning of the cranium by Pacchionian bodies sometimes require the minutest attention, especially when there are scalp wounds in the neighbourhood (*Fig.* 2).

Experience has shown that with well-prepared plates, carefully examined, it is very rarely that a fracture, however minute, is missed. The following case well exemplifies this point :—

Case 1.—Pte. M. was brought into hospital on Aug. 24, 1916, suffering from a wound of the vertex received the day previously. He exhibited slight sinus symptoms. Examination revealed a dirty gutter-wound stretching across the vertex, 9½ inches behind the nasion (nasion to inion 13½ inches), with bare bone showing. *X* rays showed a minute defect exactly over the sagittal suture, with a large flake of in-driven table under it. Two small metallic fragments were seen lying in the right cerebral hemisphere at a considerable distance from the wound of entry.

Operation was performed on Aug. 25. A flap was turned down, including the wound and a large area surrounding it. No sign of any fracture of the outer table was seen, and the sagittal suture appeared normal. It was thought inadvisable to trephine on account of the dirty nature of the scalp wound, and there seemed to be more than a suspicion that the *x* rays for once had lied. Two days later the patient's temperature suddenly rose to 103°. He became unconscious, the sinus symptoms in his legs progressed, and his left arm, which had previously been normal, became paralyzed. The flap was re-opened ; now, over an area the size of a five-shilling piece, surrounding that portion of the sagittal suture where the *x* rays had revealed a deficiency, there was a discoloured patch of outer table. Even then close examination revealed no fracture. A trephine disc was removed just to the right of the unhealthy area, and this latter was removed with forceps as far as possible in one piece. A large flake of inner table was found depressed on to the dura, and there was a small dural defect immediately to the right of the sinus, which bled freely during the course of the operation. A deep brain-track led downwards and to the right in the direction of the shell fragments. Examination of the bone removed suggested that the missile may have entered as one piece and subsequently broken up into two, passing between the lips of the sagittal suture, for no fracture could be discovered.

III. CLASSIFICATION OF THE TYPES OF INJURIES REVEALED BY RADIOGRAPHS IN RESPECT OF THE NEED FOR SURGICAL INTERFERENCE.

1. No fracture to be seen by X rays.—Previous to the introduction of the helmet, these wounds could be safely left without surgical interference, and we never had reason to regret our expectant policy ; but lately we have been struck by a remarkable series of cases, about six in number, all wounded on or about the apex of the temporal crest. These patients have come in but little affected, often showing no physical signs, or, at most, a slight facial weakness, paresis of one arm, or some aphasia. Their temperature and general

condition on admission have given no cause for anxiety. They have remained well for two or three days, at the end of which time signs of cerebral mischief have suddenly revealed themselves. Fits unamenable to bromide or morphia, increasing optic neuritis, severe headache progressing to drowsiness, with progression of focal symptoms, have all indicated urgent need for operation. On turning down a flap, at most a slight cracking of the temporal bone has been seen; more commonly there has been a considerable area of discoloration, a bluish appearance of the bone under the wound; in one case there was no change in the bone at all. There has been no extensive extradural hæmorrhage, but the dura has appeared discoloured and unhealthy. Underlying the dura, which was in most cases adherent to the subjacent brain by a layer of altered clot, a considerable cavity containing pulped brain and sanguineous material has been found in the temporal lobe. Evacuation of this collection, with drainage, has caused a gradual amelioration of symptoms, and our mortality for the six cases has been nil. The following case is typical of this class :—

Case 2.—Pte. J. was admitted to hospital on Aug. 9, 1916, suffering from a superficial gutter-wound in the region of the left temporal ridge. He stated that he was wearing a helmet when wounded. He was quite fit and intelligent on admission, but had some slight sensory aphasia. His temperature was normal. *X*-ray examination was entirely negative. He remained well until Aug. 11, when he had a Jacksonian attack, limited to the right side of his face. He also developed weakness of the right side of his face and his right arm during the day, and one fit followed another at rapidly decreasing intervals. His optic discs showed two dioptres of swelling.

Operation was performed on Aug. 11. A large flap including the wound was turned down, and it was then found that the wound was literally only skin-deep, and the underlying fascia had not been penetrated. No injury to the bone was seen. A trephine disc was removed under the wound near the apex of the temporal ridge, and a large area of bone nibbled away with forceps. The underlying dura was tense and discoloured, but had not been penetrated. A small dural flap was turned down. On incising the flap the underlying cortex was found firmly adherent to it, with a thin film of altered, adherent, sticky blood intervening. Underneath was a considerable cavity in the temporal lobe, containing much disintegrated brain substance mixed with sanguineous purulent material. This was evacuated, and the cavity drained through the scalp wound by a rubber tube. The following day the patient was very ill and collapsed, and had several fits, but after that he steadily improved, and has since gone home.

It has seemed to us from a study of the above series of cases that this phenomenon is due to a 'whipping' of the temporal bone, which, unlike the other components of the skull cap, is unprovided with a diploic splint. Consequently considerable damage may be done to the underlying brain, although no fracture is revealed. An important causative agent is also probably the fact that the buffers in the lining of the helmet are in close contact with the head in this region. In other regions where no fracture is shown we have had no such difficulties.

2. **A small bone crack, usually limited in extent, with no sign of in-driven fragments.**—These cases we generally left alone, as it is difficult to see what can be gained by operative interference.

3. **Extensive fissured fractures without depression.**—These are often serious, running down to and involving the base of the skull. We usually left

them alone unless urgent symptoms manifested themselves. It is important to note that the dura is frequently nipped up in the fissure, and may be much damaged at the time of operation unless the fact be borne in mind. Fractures of this nature are generally due to the impact of a large blunt object, such as a big shell fragment or nose cap, on the skull. We believe that skulls showing extensive fissured fracturing have increased in relative proportion to the other types of wounds since the introduction of the steel helmets.

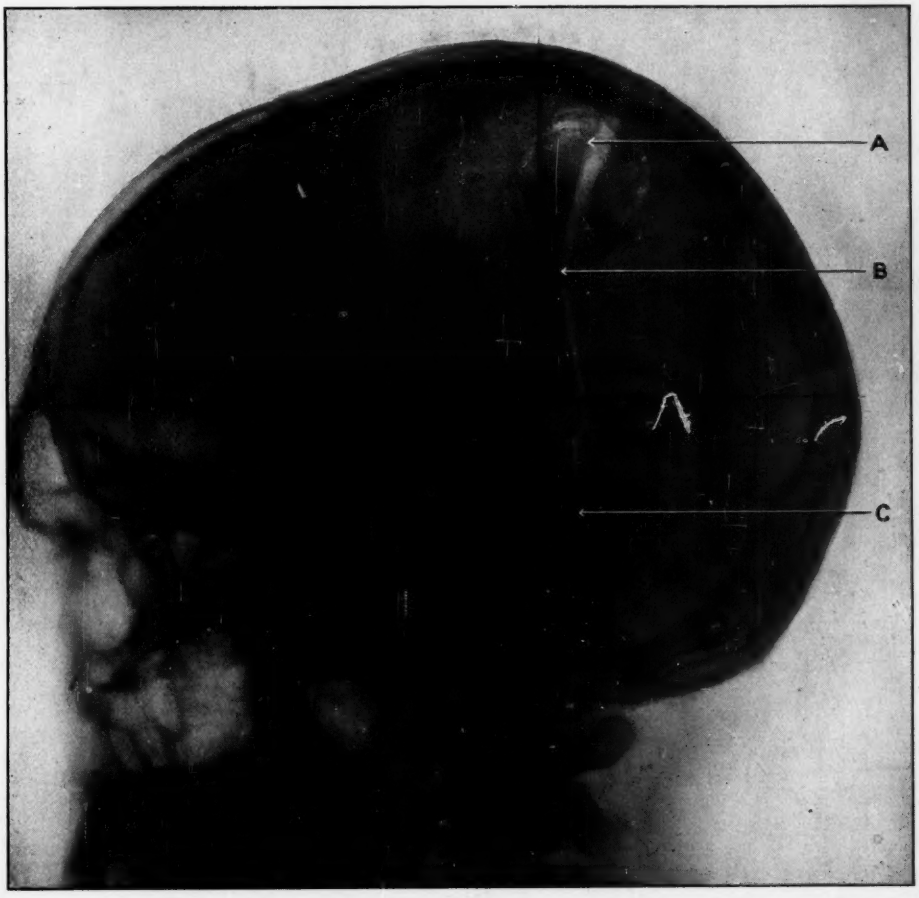

FIG. 3.—Gutter fracture, with limited depression of the inner table and with extensive fissured fracture extending to the base. A. The light area is the actual outline caused by the wound in the scalp; B. Dark circular lines mark the depressed inner table, which does not penetrate the dura. C. Fracture, which can be followed stereoscopically as far as the foramen magnum.

4. **Gutter fracture with only limited depression of the inner table.**—The outer table remains more or less in position. The injury in these cases is only shallow, and often it can be safely prophesied that no injury to the dura beyond bruising has occurred. To this class belong the 'lid-like' fractures, the two lips of the lid being inverted in a valve-like fashion (*Figs.* 2 and 3).

We have made it the usual practice to operate for the removal of these depressed fragments, unless the fracture is over the longitudinal sinus.

5. **Gutter fracture with considerable in-driving of the inner table.**—The brain underlying the fracture is penetrated by bone fragments to a greater or less extent. The contour of the outer table is still more or less preserved. In this class we have operated on every case.

FIG. 4.—*Position* 1. The lobulations of the brain are visible, especially in the frontal convolutions. Two large defects in the skull are shown, caused by multiple wounds. A. Depression to the right of the middle anterior frontal. Metal in scalp; no metal in brain, but a track passing inwards for 2½ inches; B. Linear fracture passes backward as far as posterior parietal; C. Large depressed fracture to the right and below the torcular; D. Metal in wound entrance; E. External auditory foramen; L. Lambdoid suture resembling a fracture.

6. **Penetrating wounds with no missile in the brain** (*Fig.* 4).—In this class there is a definite defect involving both tables. Fragments of bone are driven into the brain to varying depths. Such cases almost invariably require operative interference, and generally at the operation a dirty brain-

track is found containing bone fragments and pulped septic brain material. The chances of the patient's recovery seem to vary inversely with the length of the track, those communicating directly with the lateral ventricle being very fatal. Penetrating wounds below the tentorium cerebelli are also of bad prognosis (*Fig.* 5).

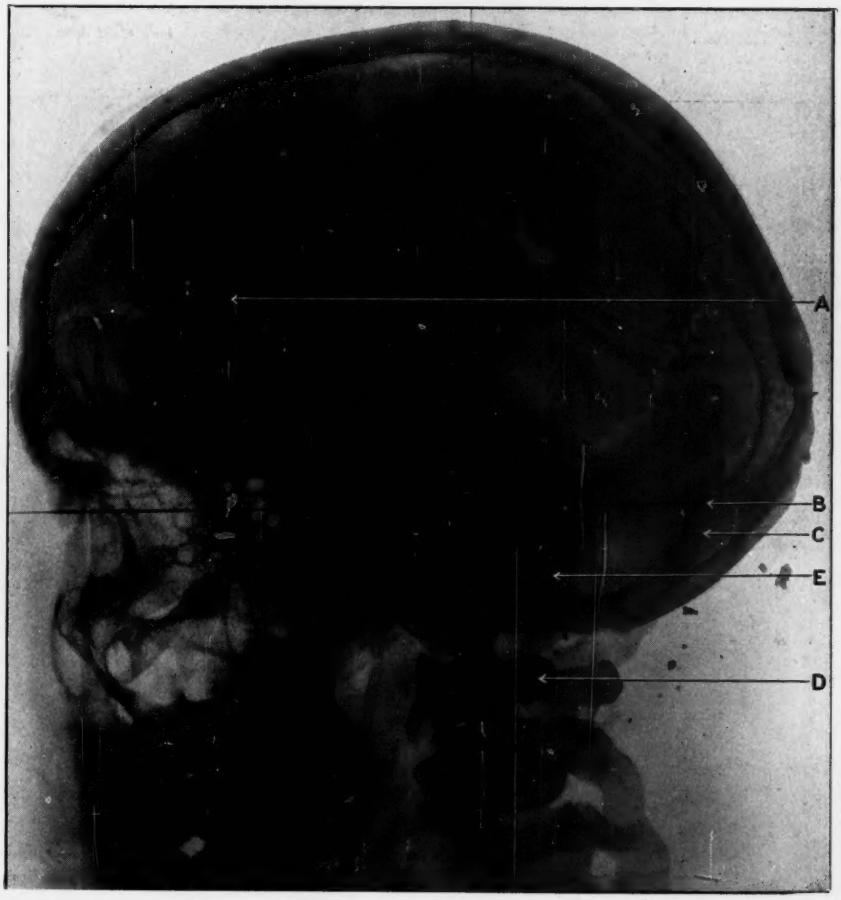

FIG. 5.—*Position* 4. Multiple injuries. Ring over wound in left mid-parietal area. Defect in skull, with track passing into brain for a distance of over an inch. A. Fracture passing directly forwards to anterior frontal; B. Large second wound and bony defect in right occipital, just above and to the outer side of the torcular C; D. Large piece of shell, which has passed through the occipital wound, tunnelled the base of the skull, and emerged at the level of the base of mastoid and to its inner side; E. Marks the exit. The lateral sinus was opened up. The lambdoid suture is well seen.

7. Wounds with one or more missiles retained, either in the bones of the skull or in the brain.—

a. The missile may actually be arrested in the bone.

In some cases the projectile has penetrated the outer table only, leaving the inner table intact. A trephine disc has been removed, comprising the outer table, with the missile firmly stuck into it, leaving the inner table and

a great part of the diploe intact. Both tables may be penetrated, a part of the missile lying firmly wedged in the bone. In one case the foreign body, a thin sickle-shaped fragment of helmet an inch in length, had penetrated both tables. Its lower end was driven through the dura for fully a third of an inch, while its upper end just protruded above the outer table.

b. The missile may have passed entirely through both tables of the skull, and be lying between the inner surface of the skull and the dura, the dura still being intact.

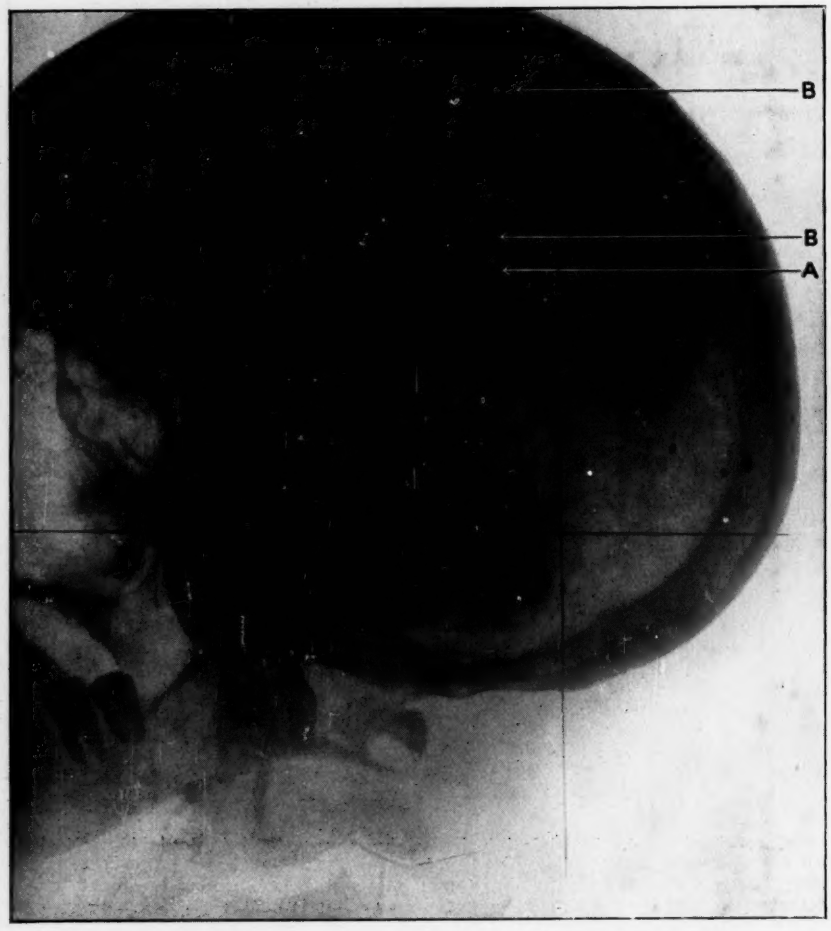

FIG. 6.—*Position* 2. Pte. C., admitted April 19, 1916, died the same day. A. A large circular defect in the right posterior parietal region. Edges of defect are lined by numerous small metal fragments. All the larger fragments are in the wound track crossing the brain almost to the other side of the skull; B. Shows the largest fragments, all of which are furthest removed from the wound of entry. Extensive fissured fractures extend horizontally forwards to the frontal region and backwards to the upper occipital.

We have had a number of cases of this variety, and have operated on every one, with no mortality. In certain cases the missile has penetrated the dura and has sprung back, lying between it and the inner aspect of the skull.

In several cases in which this has happened the brain has become infected underneath, and the missile has been found at the operation to have formed the cork to a large brain abscess.

c. One or more missiles may be lying in the brain substance at varying depths from the wound of entry.

The missile usually forms the base of a cone, the apex of which is at the wound of entry into the brain. This cone is made up of pulped brain tissue and bone fragments of varying sizes. In those cases where the missile is made

FIG. 7.—*Position* 4. A. Wound of entry of shrapnel ball just to the left of the vertex, where some small metallic fragments may be seen lying in the scalp; B. Downward track showing lead shavings in the brain; C. A large misshapen ball lying in the left cerebral hemisphere; D. Auditory meatus.

of lead, say a shrapnel ball, small shreds of the outer covering of the ball are shed along the track, and may be seen as glistening white specks (*Fig.* 7). As a result of this 'moulting' process, the ball itself may be very much misshapen. It is interesting to note that the larger bone fragments lie at a greater distance from the wound of entry, and consequently nearer the missile, than do the smaller, and it is quite the exception to find any of these at a greater depth

than the missile. Often, if one of the larger of these bony fragments be lying turned on edge, the shadow cast by it approximates to that cast by a small piece of metal, and it may be difficult to determine which of the two it is. The importance of determining whether any missile be of lead or some other metal is apparent when the question of its possible removal by a magnetic rod comes to be discussed. (See *Figs.* 6 and 7.)

We have come across several instances where the missile had penetrated the brain, and lay on or near the bone on the opposite side of the cranium. The foreign body retained is generally a large piece of iron casing; in some instances fractures of the bone were found near the position of the foreign body, showing the position where the missile had struck the bone, but its momentum was not sufficiently great for it to penetrate and pass onwards.

Various Types of Missiles met with.—In the early days, during the first and second battles of Ypres, we passed through a phase when many shrapnel balls were retained in the skull, our record case being one in which five such balls were embedded in one brain; but lately, since the almost universal adoption of high-explosive shells, these have been seen but rarely.

Rifle bullets are comparatively seldom seen, but during the past year we have had several such cases. The wound of entry caused by a rifle bullet is often small and easily missed, and commonly no bone defect can be felt. The patient is often surprisingly well, and in at least one case it was only by chance that an *x*-ray photograph came to be taken.

Case 3 (*Fig.* 8).—Gunner C. was admitted into hospital on July 1, 1916. He was wounded on the night of June 30. There was a fight between two aeroplanes going on overhead. He was wearing no helmet, and thought that he had been struck by a shell fragment from an anti-aircraft gun. He had a tiny wound of the vertex 5 inches behind the nasion (nasion to inion 14 inches) and ¾ inch to the right of the mid-line. There was some œdema around the wound. *X* rays showed a small opening in the skull under the wound of entry, with a brain-track passing down to the base of the skull, where lay a rifle bullet behind the right orbit. The apex of the bullet was sticking into the hard palate. Beyond a slight frontal headache and some drowsiness on admission he had no physical signs, and was evacuated to England on July 14, no operation having been performed.

Nowadays shell fragments form by far the greatest proportion of missiles; commonly there are one or two, but in some cases, mostly hopeless, we have seen dozens of such fragments embedded in the brain (see *Fig.* 6).

Operative Treatment.—Whilst tempted, in the early days, to operate on every case, and attempt removal of the missile if not too hopelessly inaccessible, lately we have adopted much more expectant treatment. If the missile be deep and the wound of entry clean, we have left it untouched unless urgent symptoms arise. The following is a good example of the small amount of damage that a number of missiles embedded in the brain may do.

Case 4.—Pte. T. was admitted to this hospital on June 17, 1916, suffering from a grazed wound of the frontal region, evidently only superficial. He gave a history of having been wounded the previous March by a rifle grenade at the back of the head. This wound must have caused him little trouble, for he was back with his regiment nine days later. After rejoining he noticed a difficulty in controlling himself, becoming easily excited when in the fire trenches. He had been discharged from the army in 1906 for insanity, and was put into a lunatic asylum for some time by his own people. He also had a bad family history of insanity. It is not to be

wondered at, therefore, that he became excited while under fire, and his wound probably had little to do with the condition. He was also gassed on April 29, but not sufficiently badly to leave his unit.

Examination of his head revealed the recent graze over the frontal region, and a tiny, perfectly healed wound of the occipital region 1 inch above and 3 inches to the right of the inion. *X* rays showed no fracture under the recent frontal wound, but a small defect of the occipital bone under the old wound, with a shell fragment and many small pieces of bone embedded in the right occipital lobe. He seemed normal in every way, and showed no sign of intracranial injury. He was evacuated to England on June 20, apparently quite well.

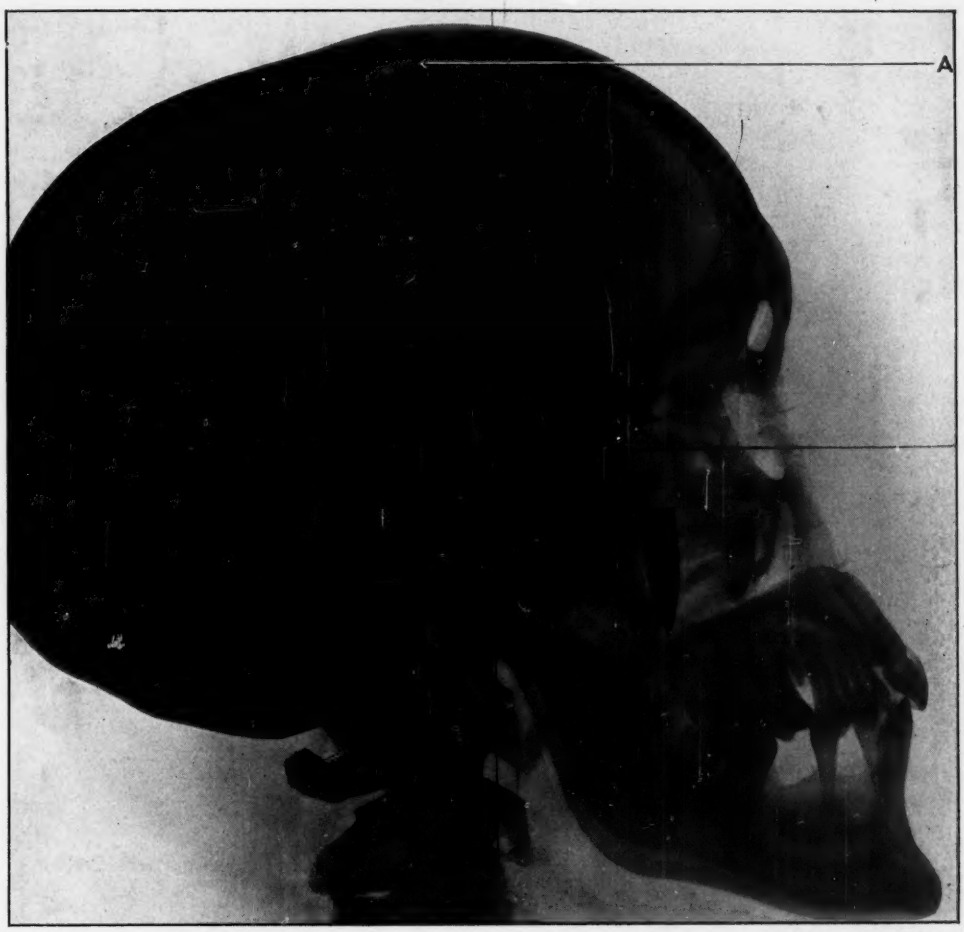

FIG. 8.—*Position* 1. Gunner C. (*Case* 3.) A. Marks a tiny perforation of the skull near the vertex. From this a bullet has passed through the brain and the base of the skull just behind the right orbit, and is lying with the apex embedded in the hard palate. The track of the bullet is very faintly shown.

When the wound of entry is septic, and especially if pulped brain be oozing from it, operative interference of some sort is imperative. Where the foreign body is inaccessible, two inches or more from the opening in the dura, it has been found advisable to do nothing more than clean up the wound of

entry, removing the superficial in-driven bone fragments, and if the track be not too hopelessly septic, drain by lateral rubber tubes placed in at the angles of the flap after excision and suture of the excised edges of the wound of entry. We have resorted to direct drainage of the track through the wound of entry for the most part only when we have judged it to be very septic.

FIG. 9.—*Position* 1. (*Case* 5.) Wound track through brain distended by infection with gas-forming organisms. A. Point of entrance; B. Small fragment of shell lying in end of track underneath pia mater. The large main track runs directly through the left cerebral hemisphere, and is much larger than the entering missile. Its wavy appearance is caused by side pockets of gas contained in tracks which pass laterally; C. A tiny fragment slightly above the pituitary gland lying at the end of a track which passes in a crescent direction downwards and forwards from about the middle of the main track. The patient survived for five days after this radiogram was taken.

In one extraordinary case (*Case* 5) we were able to show by *x* rays a brain-track giving a peculiar wavy appearance, due, as autopsy subsequently revealed, to a gross infection of the track with gas-forming bacilli.

Case 5.—Pte. R. was admitted to hospital on May 22, 1916, suffering from a wound received on May 17. He brought a note down with him from the casualty

FIG. 10.—(*Case* 6.) There is direct bruising of the scalp around the entry-wound over the right frontal region. The hæmorrhage around the eyes has been extravasated from bleeding within the anterior fossa. The forehead is deformed by the uplifted fragment of the frontal bone.

clearing station saying that a decompression operation had been performed around the wound of entry on May 19. He had a deep gaping elliptical wound, 11½ inches behind the nasion (nasion to inion 13 inches) and 2½ inches to the left of the mid-line. The brain was exposed at the bottom of the wound.

X-ray examination (*Fig.* 9) revealed a large bone defect in the left occipital region, with a small shell fragment just inside the opening. From this an extensive wavy track passed forward to the frontal region, where lay a shell fragment small out of all proportion to the very large track along which it had passed. From the

FIG. 11.—*Position* 1. (*Case* 6.) Perforating wound of frontal region, showing large 'expressed' fragments of frontal bone, comprising both tables, between the wounds of exit and entry. The ring marks wound of entry.

centre of the main track a subsidiary track passed downward, forward, and inward, terminating in the region of the pituitary fossa, where there lay another small fragment of metal. A tentative diagnosis of gas-gangrene infection of the track was made, to account for this unusual appearance. The patient was comatose on admission, and died a week later. Autopsy revealed a very extensive brain-track, showing obvious gas-gangrene infection, passing forward in a manner shown in the radiograph.

8. **Perforating wounds, with entry and exit wounds present in the skull** (*Fig.* 5).—Wounds of this type have been comparatively rare, especially since the universal adoption of the helmet by our troops, but a certain number have passed through our hands.

Biparietal perforating wounds, usually caused by a rifle bullet, have perhaps been the most common examples of this type, and often in the cases that arrive here, surprisingly little damage appears to have been done to the bone or brain. In one case, Pte. M., a detailed report of which has already been published,* a shrapnel ball had passed through the brain from one parietal region to the other, and was found by *x* rays to be lying between the temporal muscles and the bone on the side opposite to that by which it had entered. Beyond slight apraxic symptoms the patient seemed little the worse for his injury, and was able to walk a few weeks later. We have heard with regret that this patient has since died after a secondary operation for removal of bone fragments.

Perforating wounds of the frontal region have usually been very severe, the frontal bone being very extensively fractured and broken up, with great destruction of the underlying frontal lobes.

Case 6 (*Fig.* 10).—Pte. A. was admitted on Aug. 22, 1916, suffering from a rifle-bullet wound of the frontal region received on Aug. 16. He was wearing a helmet, and the bullet must have traversed the helmet. He was unconscious for a time, but recovered sufficiently to walk from the trench where he was wounded to the dressing station. The wounds of exit and entry are well shown in the figure. There was much bruising and discoloration over the whole area included between and surrounding these two wounds, and the whole scalp appeared uplifted in this region, giving the patient an appearance uncommonly like that presented by a case of congenital 'tower-skull'. There was also much bruising and discoloration around both eyes, but no proptosis.

X rays (*Fig.* 11) showed a large plate of the frontal bone uplifted between the wounds of entry and exit; from this a linear fracture passed back to the region of the right coronal suture. There were no bone fragments driven into the brain. His only symptoms were some drowsiness and severe frontal headache. During the first few days after admission his condition gave rise to anxiety, and the bruising and discoloration increased to an extent we had not hitherto seen. After the first week, however, he improved, the bruising subsided, and an *x*-ray photograph taken just before discharge to England on Sept. 8, showed the displaced plate of the frontal bone beginning to drop into position again.

Although great bruising around the eyes, indicating a fracture into the anterior fossa, has always been common in frontal injuries, it is only lately, since the introduction of the helmet, that cases showing severe mottling of the scalp, usually of a purplish tinge, have appeared. In the above case it was probably due to squeezing of the scalp tissues between the uplifted bone and the under surface of the non-yielding helmet.

Perforating wounds of the occipital region have been rarely seen, doubtless on account of their early fatality.

We wish to express our indebtedness to the Medical Research Committee for the use of the coloured plate.

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* Smith and Holmes, "A Case of Bilateral Motor Apraxia with Disturbance of Visual Orientation," *Brit. Med. Jour.*, 1916, March 25.

REPAIR OF INJURIES TO THE SKULL BY PERFORATED PLATES.

By A. B. MITCHELL, Belfast.

Head injuries in the war are so numerous and so serious in their sequelæ that any means of minimizing their ill effects must be worthy of consideration. For some time past I have been in the habit of repairing gaps in the skull by the use of very thin perforated silver plates.

The silver is rolled out a little thinner than an ordinary visiting card, and is then punched with holes one-eighth of an inch in diameter, as close together as possible. This has the following advantages:—

1. Being very thin the plate can be readily adapted to the convexity of the skull.

2. The perforations have the advantages that they lighten the plate; they admit of the escape of blood or other fluid, so as to avoid compression by accumulation between the plate and the dura or brain; and they provide a simple means of fixing the plate in position.

Technique of Operation.—The plate, which can be cut to any required size by strong scissors, is applied as follows:—

1. A large flap of scalp is turned down.

2. The opening in the skull is explored, any foreign body is removed, adhesions are freed, and bleeding is arrested.

3. The periosteum is now carefully raised from the skull for about half an inch all round the gap.

4. The plate, cut the necessary size and shape (half an inch in diameter larger than the opening it is desired to close), is now slipped under the reflected periosteum and fixed in position by a series of catgut sutures which, by the aid of a fully-curved needle, are carried through the periosteum and out through any of the perforations in the plate which are most convenient. In this way the plate is securely fixed in position and cannot slip. The scalp flap is now sutured in position, and a drainage tube inserted at the most dependent angle for twenty-four hours—otherwise a hæmatoma is very likely to form.

Needless to say the most rigid asepsis must be observed.

The following case illustrates the benefits of this operation:—

Bullet Wound over Left Motor Area.

I. O. R., age 20, was wounded August 26, 1914. The bullet, which was found on the cortex of the brain, was removed at a French hospital. His right side at that time was completely paralyzed. He gradually improved, and at the end of fifteen weeks was able to stand on the right leg, and ultimately regained almost complete power over his right side. In January, 1915, he began to have typical Jacksonian fits, commencing in the right foot and spreading to the right arm and face. When admitted to my ward in the Royal Victoria Hospital, May 5, 1915, he was having as many as fourteen fits per day. He had a crucial scar and a depression about the size of a penny over the left motor area.

When the scalp was reflected we found a cyst about the size of a hazel nut on the cortex of the brain, in the centre of which was a small irregular piece of bone. This was removed, and the gap in the skull repaired by a perforated plate as described above.

He had a fit the evening after operation, but has had no recurrence since that date. He is now (Dec. 16, 1916) at work and in good health, nineteen months after operation. A radiogram, taken by Dr. Rankin two months after operation, showed the plate still in position.

The largest plate I have yet applied was $4\frac{1}{2}$ inches by $2\frac{1}{2}$ inches. The patient, who was under the care of Dr. St. George in the County Infirmary, Lisburn, was injured by shrapnel on April 13, 1915. At the time of operation, Dec. 14, 1915, he was a confirmed epileptic. He had a large scar on the right fronto-parietal region, just in front of the motor area. This scar was depressed, adherent to the brain, pulsated freely, and was very tender.

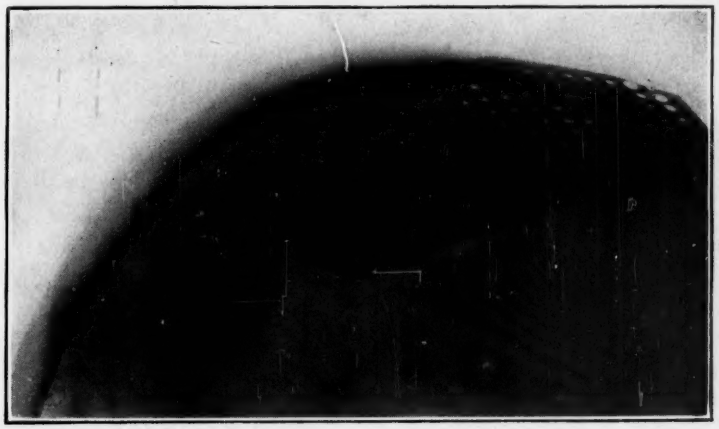

FIG. 12.—Radiogram showing perforated silver plate in position on the skull five months after operation.

With the assistance of Dr. St. George, the skull was plated on April 13, 1916. The accompanying radiogram, kindly taken by Dr. Rankin on Sept. 22, shows the plate in position five months after operation (*Fig.* 12). He still has some fits, but they are not nearly so frequent or so severe as before operation.

I have now operated on six of these cases. In every instance primary union was obtained, and marked relief followed the operation. None of the plates gave rise to any trouble.

THE REPARATION OF CRANIAL DEFECTS BY MEANS OF CARTILAGINOUS GRAFTS.

By H. L. WARREN WOODROFFE, Lyon, France,
Surgeon to the Ulster Volunteer Hospital.

The problem of the reparation of cranial defects has latterly become one of extreme importance. Before the War it was, on the whole, rare to find cases in which large gaps had to be left in the skull, except where decompression was performed for increased intracranial tension, when it was obviously to the patient's advantage that the opening should remain patent. Now, we see on every hand cases of fractured skull, and they are nearly always accompanied at first by septic infection of the brain and meninges; a fact which renders free removal of bone an imperative necessity, both for purposes of drainage, and for relief of the temporarily increased cerebral tension. Hence, not only is trephining a far more common operation than formerly, but with increased experience large openings have become more and more the rule, and this in men to whom a permanent cranial defect can be no possible benefit.

There are many cases of trephining in which no reparative operation is advisable: the small trephine hole, made for a fissured fracture, and revealing an intact dura mater, has long been known to cause no trouble. But we do not very often have to deal with such cases in military surgery. Where the breach is large, as it usually is, the question of reparative operation is always to be considered.

The position of the gap also makes a difference in the symptoms caused. When it is opposite the attachment of the falx cerebri or tentorium cerebelli there are rarely any symptoms of importance, so much is the dura strengthened from within. One might indeed say (physiologically speaking) that in such cases one has to deal with two small openings rather than one large one. But the possibility of one of the great sinuses being involved in any subsequent injury to the defenceless spot must be kept in view. Wounds of the squamous temporal bone are protected by the temporal muscle and fascia, unless these are too much destroyed. But where the frontal, the parietal, or the occipital bone (above the superior curved line) is affected, it is the rule and not the exception to find symptoms of unstable intracranial equilibrium.

What then are the signs and symptoms which should lead a surgeon to advise operation in these cases? It is not always easy to know how far symptoms should be attributed to the cranial lesion, and how far to some underlying cerebral condition. It is therefore well to assure oneself that there is no foreign body lying overlooked in the brain and really causing the trouble; should such be found, its removal (if practicable) is the logical prelude to any attempt at repair of the skull.

The two most important signs—they always go together—pointing to a

seriously weakened state of the cerebral defences, are visible pulsation, and impulse on coughing. In severe cases a definite bulge may even be seen on the occasion of any quick movement. The presence of these signs may depend on the size of the hole, on its position, on the state of the underlying dura, or on all of these together. Whatever the cause, they indicate that the equilibrium of the brain is affected, that any movement jars the delicate cortical tissue against the unyielding edges of the aperture, and that a state of affairs is present which calls for remedy.

The symptoms most complained of are headache, vertigo, and sudden blurring of the vision. Though these are common symptoms of cranial and intracranial trouble, they may fairly be laid to the charge of the cranial defect when they are brought on by sudden movement. Inability to sleep, except with the head raised or tightly bandaged, and objection to noise, are also complained of. These symptoms can often be cured by a cranioplasty. We see also cases where the patient complains of pain and giddiness when the slightest pressure is applied to the affected spot; or where he is obsessed by the fear that any blow will result in sudden death, and begs for a protective apparatus. The value of such apparatus is very doubtful. It may be useful against outside injury, but it cannot protect the brain from constant traumatism against the edges of the gap; in any case the constant wearing of a tightly-fitting head covering is wearisome, and the result desired is far better obtained by an operation which secures a permanent and physiological protection.

It is doubtful whether unstable intracranial equilibrium alone is a frequent cause of Jacksonian epilepsy. But in any such case of epilepsy operation is advisable, with a view to the discovery and removal of the cause; and if at the same time the defect can be closed without any great increase of the shock and risk of the operation, there is no reason to refrain from so doing. There are cases on record where no cause for the epilepsy other than the cranial breach was found, and where the mere reparation of the skull has effected a cure.

Finally, and an important point in frontal wounds, the cosmetic result must be considered. A depressed, discoloured scar on the forehead is an unsightly thing; its removal is in itself well worth an operation—certainly many are performed for as little or less.

Contra-indications of the Operation.—These come under two headings: (1) General; and (2) Local.

1. The former are those which have to be taken into account in the case of any operation of expediency. No surgeon of course would operate, except in a case of extreme urgency, on a diabetic, a consumptive, or a man with advanced heart disease or Bright's disease. But such cases rarely come into the sphere of military surgery, and it is with this branch that we are mainly concerned. Bronchitis is a contra-indication: where any cough causes a cerebral impulse, frequent coughing would tend to displace any material used to fill a gap in the skull; moreover, in the case of the operation we propose to describe, where the grafts are taken from the lower costal cartilages coughing is painful in the extreme during the first few days after operation.

So, if any bronchitis be present, measures should be taken to cure it before proceeding to a reparation.

2. The local contra-indications are two: One should not operate while there is anything present to favour sepsis—that is to say, not until the wound has healed and the last scab dropped off. Nor should one repair the cranial gap while there is any marked bulging or any sign of increased intracranial tension. The mere size of the gap is no contra-indication, except in so far as some are too small to be worth repairing; no gap compatible with life is too large to be repaired, and the larger the gap the greater the need for repair.

Forms of Operation.—Many are suggested. Following Mauclaire, we may classify them thus:—

1. *Periosteal, Osteo-periosteal, and Cutaneo-osteo-periosteal Cranioplasty.*—These operations, to be efficient, involve the removal of part of the outer table of the skull adjoining the breach. This is a matter of some difficulty, with considerable shock, and necessitates the use of expensive apparatus such as an Albee's bone set.

2. *Bone grafts.*—These may be autoplastic, making use of the ribs (Kahle), great trochanter (Mauclaire), scapula (Leclerc), or tibia (Delagenière); these are all operations of some magnitude, and involve a considerable waiting period. The use of homoplastic grafts is limited by the difficulty of finding a suitable subject to take them from. Heterogenous grafts may be used—for example, the bone of a dog (Macewen, Ricard)—but these are open to the same objections as all heterogenous work.

3. *Sterilized decalcified bone* may be used.

4. *Prosthetic methods*, such as the use of plates of gold (Estor) or ivory (Mauclaire).—These may give excellent results, but they are open to the objection urged against the introduction into the tissues of any non-absorbable foreign substance—that it may, and often does, come to act as an irritant. While this does not matter much in the case of a bone plate which can be removed when its work is done, it is a serious thing when the removal of the foreign substance would undo all the work of the operation.

5. *Cranioplasty by means of cartilaginous grafts.*—This is to our mind the best and most universally applicable of all. It is at once safe and simple, and the shock is minimal; the grafts are autoplastic.

The operation, first described by Morestin in February, 1916, consists briefly in the filling of the gap with grafts taken from the lower costal cartilages. It was brought to our notice by M. Villandre, of Lyon, who is responsible for some notable improvements in the technique. The advantages are as follows:—

i. The grafts are autogenous.

ii. The shock to the patient is very small, the suffering entailed is not great, and the risk in suitable cases is practically nil.

iii. The object is rapidly attained: most patients leave hospital with a solid skull at the end of a month or five weeks.

iv. There is no need to wait, as in the case of bone grafts, for several months after the wound has healed before proceeding to operation; the cartilage appears to possess a power, unknown to bone grafts, of resisting

infection. Villandre reports a case where, in spite of a mild suppuration, the grafts survived and solidified. We have operated on more than one case less than a week after the last crusts had separated, and had no reason to regret it. Villandre repaired thirty-two out of his first sixty-four cases less than four months after the injury was received. This is a point of great importance in military surgery.

v. The operation is not a difficult one, and requires no special plant.

vi. In frontal cases it gives an opportunity for moulding, and readily allows of cosmetic results only obtained with difficulty by other methods.

TECHNIQUE OF THE OPERATION.

Preparation of the Patient.—The entire scalp is shaved, and the eyebrows if necessary, as are the chest and upper abdomen. The skin of the operation areas is disinfected with iodine, and surrounded with sterile towels (those over the chest should be covered with another until such time as the grafts are to be cut). A screen is absolutely necessary between the anæsthetist and surgeon, and attached to the patient's forehead, not only for asepsis, but to serve as a point of attachment for hæmostatic forceps used to retract the skin flaps.

The Anæsthetic.—The anæsthetist works under difficulties, so if possible some dosimetric apparatus should be used. Whether chloroform or ether be employed does not seem to matter. Deep anæsthesia is only necessary when cutting the grafts. In France, regional anæsthesia is often used; but though this abolishes the otherwise necessary proximity of operator and anæsthetist, it is not to be recommended; very thorough anæsthetizing of several intercostal nerves (the 5th to the 9th) is necessary. The operation offers a field for the rectal administration of ether, to which we propose to give a trial.

The Skin Incision and Resection of Fibrous Tissue.—The area of the wound is most frequently found occupied by fibrous tissue, which, if on the forehead, is very disfiguring, and in any case gives an insecure hold to stitches. The incision should therefore allow for a free resection of this, and should leave at least a sixteenth of an inch of healthy skin to be resected along with it. From the periphery of this wound cuts may be made as desired, if more room be needed. If the original wound has been sutured, and there is no cicatricial tissue to be excised, one should keep to the old line.

The classical horseshoe flap should not be used, for it is apt to leave a pocket which encourages the formation of a hæmatoma (see *Case* 2). Indeed, if the original incision has been a horseshoe one, it is best to discard it (except on the forehead, when for cosmetic reasons it must be adhered to), and make a crucial incision with the cross over the middle of the hole, giving four triangular flaps. An exception to this rule is in wounds involving the temporal muscle—the splitting of which barely gives room to work—when it is best to turn down a flap. The flaps thus marked out are carefully dissected back until the whole of the cranial gap is felt to be exposed. The plane of dissection is the sub-aponeurotic layer; if this be carefully adhered to, it is easy to bring the skin edges together later, and compensate without undue tension for quite large cicatricial areas (see *Figs.* 16, 17).

We now proceed to the excision of the island of scar tissue left in the middle. Here one must work with the greatest care, remembering that the dura has probably been injured and may only be represented by a thin layer of fibrous tissue. The plane of dissection should therefore be kept close to the surface. Should there be an escape of cerebrospinal fluid, the rent should at once be sutured ; if this be impossible owing to the friability of the tissues, a muscular or fascial graft should be used.

The Cleaning of the Edges of the Gap.—The pericranium is incised with the point of the knife, keeping as close as possible to the edge of the gap. This must be done with great care, as a slip might have disastrous consequences. Bleeding is usually so free as to obscure the vision, and the work has to be done by touch. When completed, the edges of the aperture are carefully cleared with a rugine. This must be done thoroughly, right down to the dura, and the surgeon must not be satisfied until he can sweep the edge of the rugine round between the deep surface of the skull and the dura mater (*Fig.* 13).

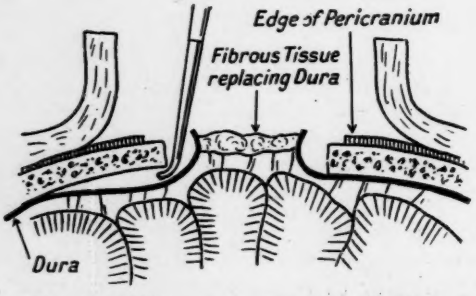

FIG. 13.—Diagram to show the clearing of the margins of the bone opening, including the separation of the dura on the deep surface.

Should this step be inadequately carried out, a projecting spine may be missed on the deep edge of the hole, which might cause epilepsy by pressing on the brain. All roughnesses or projections are removed with a gouge forceps. Any slight cerebral hernia present now falls back, or can be gently pressed into place (the operation should not be undertaken in the presence of more than a very slight degree of hernia).

The surgeon is now faced by a clean hole in the skull, displaying a mass of fibrous tissue with slightly raised edges. It is an easy matter to scrape this mass away with a curette, but it should not be done. To begin with, the dura may be non-existent, and such a proceeding would only open up the sub-arachnoid space. Even if this complication be avoided, there is very free oozing: in two cases (*Cases* 3 and 4) we ascribe the formation of a hæmatoma to our having taken this step. Should there be too much fibrous tissue, it is better to clip it away with scissors ; but even this is not necessary. The fear at first experienced of piling on too much tissue, and causing pressure, is unfounded ; the real difficulty is to avoid recession of the grafts, with subsequent depression.

If the dura is to be opened, it should be done at this stage; but this is rarely necessary, and should only be done when there is some definite indication of underlying mischief. A swab wrung out of peroxide of hydrogen (to stop the oozing) is placed in the wound, the flaps are turned back over it, and the head is covered with a sterile towel. If any bleeding points are found when the wound is reopened later, they can then be dealt with by under-running.

The Cutting of the Cartilaginous Grafts.—These are taken from the 6th, 7th, and 8th costal cartilages, and should for convenience be cut from

the same side as the head wound. The usual incision is one parallel to and a little above the costal margin. After our first three cases, however, we adopted a vertical one, two finger-breadths outside the edge of the sternum. This gives equally good access; can more easily be extended if necessary; the hæmorrhage is less; and it has the great advantage of splitting instead of cutting across the upper fibres of the rectus.

The cartilages having been thus exposed, shavings are taken of about half their thickness. Care should be taken not to cut through the entire thickness of a fixed cartilage; but the whole tip of a floating one may be taken. It is well to take what seems to be considerably more than enough cartilage to fill the gap. Each graft, as cut, is dropped into warm saline solution.

To facilitate this work at the bottom of a hole, M. Villandre has devised an ingenious knife, the blade of which is set on a shank, bayonet-wise (*Fig.* 14). This enables the grafts to be cut evenly by keeping the blade of the knife flat.

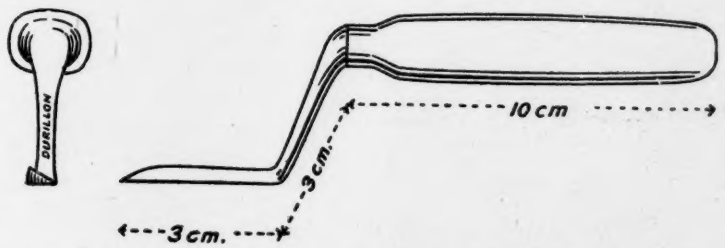

FIG. 14.—Knife with shank set at an angle for cutting grafts from the costal cartilages. Designed by M. Villandre.

In operations on the occipital region, this stage must be carried out first, and the wound sutured before turning the patient to incise the head; otherwise it is best to pack the wound with gauze, and proceed at once to transfer the grafts.

Placing the Grafts.—The chief difficulty is to keep these from slipping. To this end it has been proposed to push the edge of the graft between the skull and the dura; theoretically, this might cause a rise of intracranial pressure; practically, the edge of the skull is bound to show as a ridge. It has also been suggested to groove the diploë with a chisel, and push the grafts into the groove, a step which would certainly prolong the operation and increase the shock.

A very simple and rapid method is that of Villandre. One end of a fine catgut stitch is passed through the pericranium, and tied. It is then passed through the pericranium on the other side of the gap, and taken backwards and forwards in a zigzag manner till the hole is covered in with a trellis. In the case of a very large gap it is wise to supplement this network by a second, at right angles to it, and to insinuate the grafts between the two layers. We have now a small chamber bounded by the dura, the edges of the skull, and our trellis, into which the grafts can be slipped with a forceps (*Fig.* 15). It is advised to apply the perichondral surface to the dura, in order to avoid adhesions; in any case it is easier, as the grafts curl when

cut, the perichondrium being in the concavity. They should overlap everywhere, and may well be doubled, as some slight recession always takes place, and those cases give the best final result which, at the end of the operation, show a slight boss. When the frontal or temporal regions are involved, it is well carefully to study the sound side before operating; it is then possible to restore almost exactly the symmetry of the forehead.

Suture of the Wounds.—In this step great care must be exercised to obtain as perfect a scar as possible. If hæmostatic forceps are left on till the wound is to be closed, ligature of vessels is rarely necessary. To get perfect apposition it is well to put one or two mattress sutures in each limb of the incision, supplemented by a continuous blanket stitch, or (in the case of the forehead) by interrupted sutures of horsehair on a round needle. Where the cosmetic effect is of importance, it is advisable to begin the suture at the most invisible end of the wound. We have found it well to leave a silkworm-gut drain in the posterior corner of the wound. The thoracic wound is closed in layers. Time can be saved by the assistant doing this while the surgeon sews up the head.

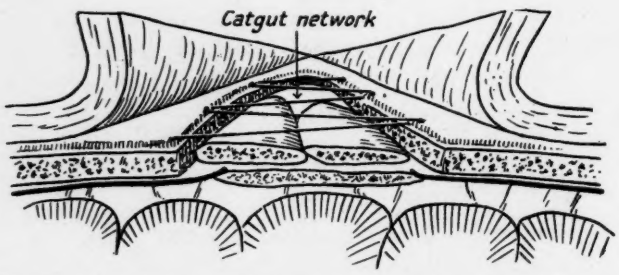

FIG. 15.—Diagram showing cartilaginous grafts inserted between trellis and dura mater.

After-Treatment.—A hypodermic injection of morphine and atropine is given as soon as the patient begins to recover consciousness. This may have to be repeated, as the pain in the thoracic wound is at first acute. The head is inspected on the second day, and the drain removed. The stitches may be removed at the end of the week, when the patient is generally allowed up. At the end of a fortnight the skull is usually hard, though slightly elastic, and all dressings may be discontinued.

RESULTS.

It is necessary to be quite clear as to what the surgeon intends to achieve when he performs a cranioplasty. It is not possible to remove troubles due to brain lesions, but only to protect the brain from further injury, especially from repeated slight trauma due to continual impact against the edge of the breach. He must, therefore, before operating, make up his mind what symptoms really are due to the cranial defects, so as to be able to explain to the patient how much relief he may expect. Viewed from this standpoint, the results are very satisfactory. It is usual to find that the headache is less, that the patient suffers less from noise, and can make efforts previously

impossible ; not infrequently he can bend forward quickly without any vertigo. These events do not come immediately, nor even as soon as the grafts have solidified ; but at the end of about six weeks considerable improvement is usually shown.

A few statistics may be helpful : Gosset, in May, 1916, reports 32 cases, with 2 deaths (from bronchopneumonia) and 30 successes ; Villandre, in October, 1916, 64 cases, with 63 successes. These observers probably count their successes from the point of view of the solidification of the breach. Marie, in reporting on 21 cases in which mechanical success was achieved, notes 6 improved as regards symptoms, 12 stationary, and 3 aggravated. This is probably an unfortunate experience. Of the 7 cases operated upon in the Ulster Volunteer Hospital, 6 have shown definite improvement in the symptoms, while all 7 have solid skulls.

As regards the military fate of the patients, very few are able to go back to the front ; it is found that the strain and noise bring on a return of the symptoms. Most of them, however—in fact, practically all who have not sustained some deeper injury—are, at the end of a few months, fit to do useful work in the auxiliary services.

The ultimate fate of the grafts has not yet been decided. Only time and the *x* rays can show whether they remain cartilaginous, or ossify. So far, radiograms taken at the end of some months tend to uphold the former view. Sicard was obliged, because of return of the symptoms, to remove a graft at the end of four months. He found no sign of ossification, or even of calcification. The line of demarcation between bone and cartilage was perfectly clear, the two being firmly fixed together by fibrous tissue.

NOTES OF SEVEN CASES OPERATED UPON IN THE ULSTER VOLUNTEER HOSPITAL.

Case 1.—Soldat F. G. Wounded on May 19, 1916, in the left frontal region. Operated on, May 20. Projectile removed from fracture of skull ; a piece of the inner table which had been driven some 3 or 4 mm. into the brain was also removed, as were several splinters from the dura.

On Admission, June 26.—A triradiate scar in the left frontal region ; depression over an area the size of a florin ; pulsation and impulse on coughing marked. No motor symptoms. Headache ; vertigo on bending forward.

Gradual cicatrization of wound.

Operation, Sept. 5.—Cartilaginous cranioplasty, with excision of the cicatrix. The gap was an irregular triangle, apex downwards, with a side of about one and a half inches.

The sequelæ were excellent. The skull was quite hard at the end of the month. He was discharged convalescent on Oct. 7. He still suffered from headache, but much less, and could bend forward without any trouble.

Case 2.—Soldat C. T. Wounded on Aug. 15, 1916. (No notes.)

On Admission, Sept. 3.—The patient presented a horseshoe scar, almost healed, on vertex. Trephine hole about 1½ in. in diameter. No pulsation ; very slight impulse on coughing ; no headache or other symptoms ; but any pressure on the gap causes acute pain.

Operation, Sept. 16.—Cranioplasty. The old semicircular flap was again raised. He developed a small hæmatoma, which was absorbed at the end of three weeks.

When discharged on Oct. 21, the skull was quite solid and he could stand considerable pressure on the grafts.

Case 3.—Soldat A. G. Patient was wounded on Aug. 2, 1916. (No notes.) Admitted to hospital on Sept. 3.

On Admission.—There was a large depression in right parietal area ; the wound was nearly healed. Marked pulsation, and impulse. Headache ; giddiness ; insomnia. Slight weakness in left hand.

Operation, Oct. 4.—Cranioplasty. A crucial incision was made The fibrous tissue covering the dura was scraped off. The hole measured about 2 in. by 2¼ in. A large hæmatoma formed and had to be evacuated.

Nearly a month after operation there was still some pulsation in the centre, but by Nov. 25 the grafts were solid, and all impulse on coughing had gone. His hand was quite strong. He still suffered from headache, giddiness, and insomnia as much as before the operation.

Case 4.—Soldat L. G. This patient was wounded on Aug. 18, 1916, and admitted on Sept. 3. (No notes.)

On Admission.—Patient presented a granulating wound at vertex. There was visible pulsation ; impulse on coughing ; headache ; and vertigo on bending forward.

Operation, Oct. 11.—Cranioplasty (Dr. J. A. Small). A crucial incision was made ; the fibrous tissue covering the dura was curetted away ; a silkworm-gut drain was employed. The defect was about 1¼ in. in diameter.

In spite of the drain, a small hæmatoma formed. By Oct. 19, however, there was no pulsation in the head, and at the end of the month the graft was quite solid. When discharged convalescent on Nov. 11, the headache and vertigo were much less.

Case 5.—Soldat J. P. Was wounded Aug. 2, 1916, and admitted Sept. 2. The notes only say "Trephined at Front—loss of brain matter—vision of right eye diminished."

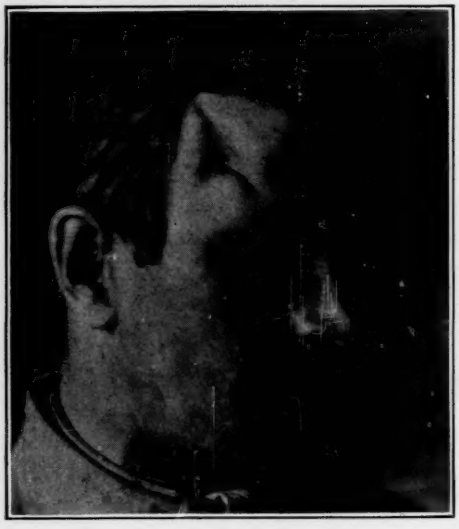

Fig. 16.—*Case* 5. Before operation.

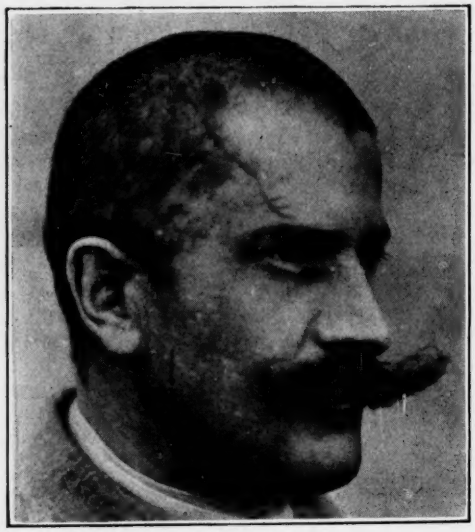

Fig. 17.—*Case* 5. After operation.

On Admission.—There appeared a depressed granulating wound above the right outer canthus. The depression was triangular, with sides about 1½ in. long. Visible pulsation, with impulse on coughing. Headache and vertigo.

OPERATION, Oct. 18.—Cranioplasty. The scar was excised, During the operation the dura was accidentally opened; it was closed. Gap about 2 in. by 1 in.; drainage.

Perfectly satisfactory healing of the wound followed, and consolidation of the graft. Patient can now (Nov. 25) bend forward with hardly any vertigo, and has had no headache for some days. The vision is clearing up. (*Figs.* 16, 17.)

Case 6.—Soldat E. B. This man received his wound on Aug. 21, 1916, and was admitted Sept. 3. The notes say: "Enlargement of scalp wound; depressed fracture of skull; fragment removed; dura intact."

ON ADMISSION.—There was a small depressed wound about 1 in. above and behind the right ear, with visible pulsation, pain on pressure, and headache.

OPERATION, Oct. 23.—Cranioplasty. A round hole about 1 in. in diameter was found.

The wound was perfectly healed on Nov. 25, and the skull quite solid. He had much less headache, and listened to an opera with pleasure.

Case 7.—Soldat F. G. This man was wounded on Aug 1, 1916, and the notes say: "Furrow in right frontal region; cerebral irritation; internal strabismus. Operation on Aug. 3: Removal of three splinters of skull from scalp; gutter fracture found; trephined; incision of dura; considerable subdural infection. Sustained improvement."

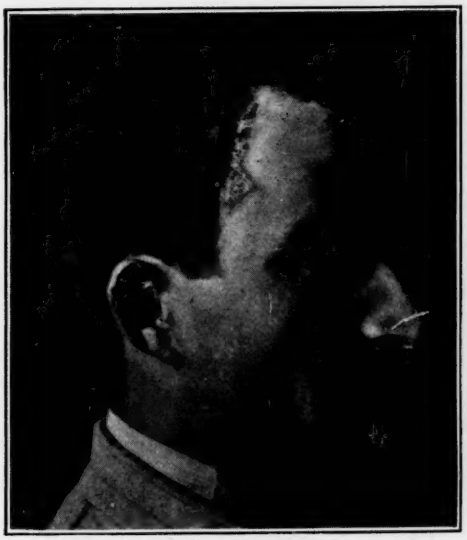

FIG. 18.—*Case* 7. Before operation.

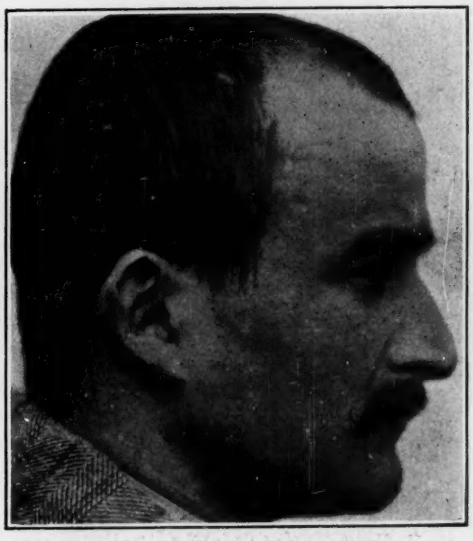

FIG. 19.—*Case* 7. After operation.

ON ADMISSION.—A granulating wound about $2\frac{1}{2}$ in. by 1 in. above and external to right eye; visible pulsation, with impulse on coughing. On Sept. 4, much better; up; cannot bend forward; and sleeps badly.

OPERATION, Oct. 28.—Cranioplasty. Excision of the scar; irregular oval gap about $1\frac{3}{4}$ in. by 1 in.

Patient had a very slight attack of epilepsy on the next day. The wound was perfectly healed by Nov. 25, and the grafts are solid. He sleeps well, has no headache, and can touch his toes with very little discomfort. (*Figs.* 18, 19.)

SUMMARY.

It appears that in six out of seven cases we have improvement, and in most considerable improvement, of the symptoms complained of. Why *Case* 3 remains in his former state it is hard to say; if his condition gets any worse it will probably be necessary to remove the graft. In *Cases* 1, 5, and 7 the cosmetic result alone was worth the trouble. Except where noted to the contrary, the technique employed was that described. We attribute the hæmatoma formation in *Case* 2 to the use of a horseshoe flap, in *Cases* 3 and 4 to our error in scraping the fibrous tissue off the dura; we have modified our technique accordingly.

To sum up: While no one would maintain that every case of craniotomy should undergo a reparative operation, a very large percentage of such cases show symptoms which can be cured by cranioplasty. While many methods have been suggested, Morestin's cranioplasty by means of cartilaginous grafts is one of the easiest to perform; it can be undertaken at a comparatively early date; it gives a very high percentage of good results; the time of waiting for these results is short, and the operation is no more dangerous to the patient than is a radical cure of inguinal hernia.

No originality is claimed for this paper, which merely sets forth the work of others; but should it do anything to popularize this most useful operation among British surgeons, the writer will be amply rewarded.

The writer's best thanks are due to M. Villandre, not only for introducing the operation to his notice, but also for much valuable help in the description of the technique, which (as here described) is almost as much due to M. Villandre as to the original author.

Figs. 13 and 15 are the work of Miss D. Stronge, senior V.A.D. member of the hospital nursing staff. The photographs were taken by M. Oulmann, of Lyon.

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SEPTIC PERITONITIS: TREATMENT BY CÆCOSTOMY.

By ARTHUR J. NYULASY, Perth, Australia.

After operation on a septic focus within the abdomen, or after the preliminary pain and shock of an abdominal catastrophe, or as the result of hæmatogenous infection of the peritoneum, the collection of symptoms known as 'septic peritonitis' may appear. In the fully developed clinical picture there are two constants, viz. (1) Intestinal paralysis, and (2) Toxæmia. We also have to distinguish two more or less distinct pathological types, namely (1) With extensive inflammation of the peritoneum and little or no free fluid in the abdomen, and (2) With much free fluid but little inflammation.

The Two Clinical Constants.—

Intestinal Paralysis.—There is cessation of the passage of gas and fæces, and bowel sounds are negative to the stethoscope, i.e., there is acute intestinal stasis.

Toxæmia.—This is indicated by rapid progressive general deterioration, the pulse and respiration quickly reaching a high grade of frequency, the blood-pressure falling greatly, restlessness and thirst becoming marked, the patient feeling weak, showing a 'dirty' pallor, and looking ill, worn, and anxious, and dying in a day or two with sunken eyes, pinched nose, livid lips, and cold, clammy, tremulous extremities; the mind being clear, or delirium or euphoria being present before the end.

Qualitatively, intestinal paralysis and toxæmia are the two clinical constants. Such symptoms as distention, vomiting, fever, and pain may or may not be prominent features. Thus, while distention is often marked, there are cases in which it is absent, the abdomen being perhaps actually scaphoid. Vomiting is frequently a striking symptom, but in some of the worst cases it may be absent. It is usually of the regurgitant type, and in rare instances becomes definitely fæcal. The vomitus often consists of dirty-looking ill-smelling fluid, with solid dark flecks distributed through it ('beef-tea vomit'). While the bowels are in most cases obstinately confined, there are instances in which actual diarrhœa is present. Whether this is due to irritation or to an overflow is not decided, but experiments on animals suggest that it is toxæmic. The temperature is a variable sign, but is likely to be subnormal with the marked prostration of the later stages of septic peritonitis. Pain and tenderness may be pronounced or very slight, being more notable in cases with extensive inflammation of the peritoneum. Pain in the diaphragmatic region is in my experience a bad sign. Tenderness is best elicited by what I call the 'staccato touch,' the abdomen being struck lightly and sharply with the tip of the finger. This may bring out tenderness as a sort of wave over the whole abdomen, while, if there is much free fluid in the abdomen, the

sound of percussed fluid may be distinctly heard ('staccato sign'). Furthermore, the staccato touch may bring on regurgitant vomiting when it has momentarily ceased. From what has been stated it will be seen that the only absolutely constant feature of septic peritonitis is the progressive general deterioration.

Quantitatively, intestinal paralysis and toxæmia vary directly the one as the other, this depending on the fact that, as the result of acute stasis, a virulent toxin is formed in the paralyzed intestines, and the more complete the paralysis the greater the amount of toxin produced. This toxin is very depressing to the circulation, as evidenced by the low tension and rapidity of the pulse, the marked prostration, the pallor, the tendency to lividity of the lips and ears, and the cold clammy extremities.

Much evidence might be advanced to support the view that the intestinal paralysis leads to the formation in the bowel of a virulent toxin. Thus, in dogs in which acute stasis is artificially produced in a loop of duodenum, a toxin may be recovered from the loop, the injection of the fluid containing the toxin into the vein of a healthy dog causing toxæmic symptoms practically identical with those in the ileus dog (Stone, Bernheim, and Whipple). In either case the clinical picture does not materially differ from that of human septic peritonitis. As bearing on the value of intestinal drainage in septic peritonitis, the life of the ileus dog may be prolonged by drainage of the loop.

The Two Pathological Variables.—The analysis of a large series of autopsies of cases dying with the clinical features of what is usually signed up as 'septic peritonitis' reveals two fairly distinct pathological types: (1) Where there is extensive obvious inflammation of the peritoneum, and little or no fluid free in the abdomen; and (2) The type with much free fluid, but comparatively little inflammation. Although, in conformity with custom, 'septic peritonitis' is here employed to refer to either, it is clear that the expression can only be regarded as clinical, and not as the name of a definite pathological entity, adequate in itself to account for death.

In reference to these two great pathological types, we find that death in septic peritonitis is due neither to the one variable nor the other. A practically universal inflammation of the peritoneum may not in itself very seriously disturb the patient, as is shown in a paper on "Acute General Hæmorrhagic Peritonitis" which I contributed to the *British Medical Journal*, July 8, 1916; and as to toxic free fluid, it is only when this is under high tension, and is inadequately combated by the protective capacities of the peritoneum, that it becomes absorbed with sufficient rapidity to produce symptoms of its own, which, where there is pus, often appear to be those of euphoria.

The main rôle of the pathological variables is to produce intestinal paralysis. In the one type direct inflammation of the intestinal peritoneum is responsible; in the other, the free toxic fluid inhibits peristalsis by acting on the intestinal nerves.

Diagnosis.—In twelve to twenty-four hours after operation on a septic focus within the abdomen, when the effects of shock and anæsthesia are usually passing off, the patient, instead of beginning to improve, may rapidly and progressively go down hill. Thus, he may look unduly distressed, the colour

may not be good, perhaps assuming a 'dirty' pallor, with a suspicion of some darkening of the lips; there may be drying of the tongue and great thirst, together with restlessness, anxiety, and complaint of weakness and abdominal pain; while vomiting, instead of diminishing, is becoming more urgent, and perhaps foul and regurgitant. The pulse, instead of being 100 or less, is 120 or more, and its tension is not good, while the respirations are 28, 29, or more. The abdomen may be distended, and show little movement, and neither gas nor fæces may be passing, although in some cases there is actual diarrhœa.

With the suspicion of a commencing septic peritonitis, every effort should be made to get the bowels to act freely, as by calomel, Epsom salts, and enemata, and by pituitrin or eserine. Also, a system of hourly records of the pulse, respiration, and temperature should be at once begun. The records are placed in parallel columns, and carefully studied. The temperature may be subnormal in the later stages, while a sudden big drop to well below the normal may indicate perforation, say of inflamed bowel. If over a period of a few hours the records show that the pulse and respiration rates are rapidly and progressively increasing, and that the pulse tension is falling, while the general condition is steadily deteriorating, the paralytic ileus of septic peritonitis may be definitely diagnosed.

By this time the pulse is probably 130 to 140 and of very low tension, the respirations 35 to 40 and decidedly shallow, the face shows a 'dirty' pallor, the lips and ears are perhaps livid, the eyes sunken, the nose pinched, while the expression is drawn, weary, and anxious, and the hands cold, clammy, and tremulous. With these signs of deterioration established, though vomiting or even distention is absent, and though actual diarrhœa is present instead of constipation, the patient will inevitably die unless intestinal drainage be promptly instituted.

I am satisfied that in the majority of post-operative cases with rapidly increasing pulse and respiration rates, but without any notable fall of pulse tension, we are dealing merely with a *paresis* of the intestines, and that stasis is as yet far from complete. Probably even with this incomplete stasis intestinal toxin is manufactured, but not in quantity sufficient to cause any marked fall of blood-pressure, although quite adequate to greatly quicken the pulse and respiration. Whether this explanation is strictly accurate or not, we have the practical fact that in many such cases free purgation soon reduces the pulse and respiration, and that the patient proceeds to recovery. My conviction is that in most of these cases the patient would, in the absence of free purgation, soon show the fall of pulse tension and the other signs which announce the presence of definite paralytic ileus.

Treatment.—In the *Australian Medical Gazette*, May 24, 1913, I described three cases of post-operative septic peritonitis apparently saved from death by intestinal drainage, the first case being dealt with on May 31, 1912. I subsequently reported three additional cases, and finally embodied these six consecutively successful cases in an article in the *Lancet* of October 9, 1915. In April of the following year (1916), papers on intestinal drainage were contributed by Mr. Sampson Handley and by Mr. Victor Bonney to the *British Medical Journal*, Mr. Handley giving "general peritonitis with obstruction" as

the broad indication for intestinal drainage, and Mr. Bonney relying largely on "fæcal and intestinal vomiting."

Mr. Handley appears to regard general peritonitis as an extensive obvious inflammation of the intestinal peritoneum, and draws a striking clinical picture of such a case where obstruction is present. He says: "Cessation of the passage of gas and fæces, and persistent foul vomit, indicate that complete obstruction has supervened . . . The abdomen is uniformly and tightly distended like a drum. The pulse becomes running, the extremities cold . . . and the patient, only within a few hours of the end, realizes . . . that he is in the inexorable grasp of death." In this advanced stage Mr. Handley believes that "the surgeon's chance has gone."

As already indicated, cases presenting a clinical picture practically identical with that so vividly painted by Mr. Handley, may show but little evidence of inflammation of the peritoneum, the only really obvious pathology being abundant fluid free in the abdomen. As to the stage in the evolution of septic peritonitis at which intestinal drainage may be successfully employed, my experience is, that, even with such a clinical picture as Mr. Handley describes, the surgeon need not despair. The following case illustrates this view.

Paralytic Ileus; Fæcal Vomiting; Cæcostomy.—Female, age 24, admitted to Perth Hospital. At operation (May 5, 1915), abdomen found full of dark blood and clots from rupture of ectopic gestation three weeks earlier. The offending tube was removed; but on account of the grave condition of the patient, the abdomen was closed while the washings were still very dark. The patient deteriorated, and within thirty-six hours obstruction was absolute, while the vomiting was fæcal and profuse, 20 ounces being ejected in one bout at 8 a.m., and then continuing till noon, by which time 18 ounces more had been ejected. The fluid had a strikingly fæcal odour, and in every way suggested the contents of the lower ileum. The pulse was now 160, respirations 40, and temperature 96·4°; the abdomen was enormously distended and immobile, the extremities were cold, clammy, and tremulous, the lips dark, eyes sunken, and the face was intensely pale. On opening the abdomen over the cæcum much dark bloody fluid welled out on to the bed; that remaining within the abdomen was only roughly mopped out. A rubber tube was purse-strung into the cæcum. Within a few hours vomiting had ceased, and in less than twenty hours the abdomen was flat, and the patient taking milk.

I find it difficult to agree with Mr. Victor Bonney that "all cases of paralytic intestinal obstruction . . . when advanced to the stage of fæcal, or short of fæcal, intestinal vomiting, should be subjected to jejunostomy." The case of fæcal vomiting just described goes, I think, to justify my attitude, since simple cæcostomy sufficed to rescue the patient.

Mr. Bonney refers to instances in which, after failure of cæcostomy alone, jejunostomy has relieved. In this connection it is important to carefully exclude possible errors of technique in the cæcostomy. Thus, I recall one case in the Perth Hospital in which, a few hours after cæcostomy, the patient became so excited and obstreperous that she had to be strapped in bed. I found the rubber drain-tube was perished, and had thus been completely occluded in tying the purse-string used to fix it in the cæcum. On putting matters right the symptoms rapidly improved, and a couple of days later she was enjoying the newspaper. In this case the patient had been in a very

grave condition—enormous distention, continuous foul regurgitant vomiting, pulse 140, respirations 40, temperature 96°, and cold, clammy extremities.

Fæcal vomiting is in my experience an excessively rare complication of septic peritonitis, although Mr. Bonney describes it as occurring in no less than five of his six cases of intestinal drainage. Although, when indubitably present, the indication for intestinal drainage is positive, still in some cases of septic peritonitis in which vomiting is practically absent, drainage of the bowel may be the one measure likely to avert death. The only true index of the urgent need for intestinal drainage is the rapidly progressive general deterioration, as indicated by the high and increasing pulse and respiration rates, the fall of blood-pressure, the drawn, weary expression, the prostration, the dirty pallor, the lividity of the lips, and the cold, clammy, tremulous hands.

Cæcostomy.—The rational treatment of the intestinal toxæmia of septic peritonitis is the removal of unabsorbed intestinal toxin and the prevention of its further production. Both these ends may be secured by intestinal drainage—provided that the peritoneal cavity is not charged with excessive poison, that the focal factor is eliminated, and that such a large quantity of toxin has not been absorbed already as to render any form of treatment futile.

The case of fæcal vomiting already described, suggests that in septic peritonitis cæcostomy alone will adequately drain the paralyzed intestines of the toxin which is rapidly destroying life, and others of my cases point to the same conclusion. I do not assert positively that cæcostomy is the only form of intestinal drainage needed in septic peritonitis, but I believe that the exceptions to this rule will be but few. The primary objective of intestinal drainage is the removal of toxin from the bowels, and if cæcostomy did not soon relieve the symptoms, drainage of the intestine higher up should be instituted in addition. Bearing in mind the possibility of such a step being demanded subsequent to cæcostomy, the hourly records should still be continued in all cases, and the patient still be watched with the most scrupulous care for at least the next twenty-four hours, saline infusion, the electric-light bath, and other measures being persevered in. If after some hours—and we cannot be more definite—improvement has not clearly set in or, worse still, there is evidence of continued deterioration, the abdomen should at once be opened under local anæsthesia a little above the umbilicus, a rubber tube purse-strung into the most distended loop of small intestine, and the abdomen rapidly closed with silkworm gut. To have carried out by Mr. Handley's very ingenious device (anastomosis of the jejunum with the transverse colon) such extra intestinal drainage coincidently with cæcostomy would have demanded exceptional daring in my case of fæcal vomiting,

In my series of cases, as soon as the opening into the cæcum was made, the fæces usually came out under high pressure, in one instance rising up in a stream over eight inches high. If the cæcum had contained this fluid before it had been opened, we may reasonably assume that the fluid would have been forced along the colon to the anus. Since this had not happened, it seems likely that these fæces had not yet reached the cæcum, but were held back in the ileum, and that the opening of the cæcum relieved the obstruction. Perhaps, then, the efficacy of cæcostomy may depend on a possible power to

relax ileo-cæcal spasm, and thereby release virulent fæces pent up in the small intestines.

Technique.—Through an oblique abdominal incision a fold of the cæcum is isolated by a pair of semicircular bowel forceps, and the parts are packed off with gauze pads. A catgut purse-string taking up only the outer coats of the cæcum is now placed, the bowel incised, and any fæces mopped away. A piece of ½-in. rubber tubing is passed into the bowel, the raw edges are turned in, and the purse-string is tied. The rubber tubing is then carried on to a bottle fixed to the bedstead, and the bowel clamp removed. A second purse-string attaches the cæcum to the peritoneum, the ends closing the internal oblique, while a couple of silkworm-gut sutures unites the skin and aponeurosis. The bowel tube becomes loose in about four days.

If, after several weeks, the cæcal fistula does not close, it may be dealt with by the simple method described by Dr. Frank Nyulasy, of Melbourne, in the *Australian Medical Journal*, and subsequently by Greig Smith in the later edition of his *Abdominal Surgery*. Semilunar incisions surround the fistula, and extend down to, but not through, the parietal peritoneum, which is then freely undermined to loosen it; the fistulous tract is removed, and the opening in the bowel sutured, the remainder of the wound being closed in the usual manner. Frank Nyulasy did his first case under cocaine anæsthesia. A fistula into the small intestine may be similarly closed three to four days after being made.

CONCLUSIONS.

In treating septic peritonitis, it is to be clearly borne in mind that a virulent toxin in the paralyzed bowels is rapidly killing the patient, and that there is only one certain method of removing this toxin, namely, by opening the intestines and draining them—always provided that before doing so the septic focus is eliminated, the abdominal cavity cleansed of excessive poison by swabbing, douching, and efficient drainage of septic necrotic areas, and further, that purgatives, saline injections, and eserine or similar drugs have been given a fair trial. As to the route, my own preference is for cæcostomy, a faith justified, I venture to believe, by my personal experience. If cæcostomy does not soon relieve, drainage of the bowel higher up should be instituted.

In military surgery I would, in a severe wound of the intestine, recommend either (1) Immediate excision, repair by anastomosis, and cæcostomy later if the patient deteriorated from paralytic ileus; or (2) Direct drainage of the injured bowel by Paul or rubber tubes for three to four days, and then repair by anastomosis.

ULCERATION OF THE COLON IN THE NEIGHBOURHOOD OF GUNSHOT WOUNDS.

By Captain JOHN SHAW DUNN, R.A.M.C. (T.C.),
and Captain HAMILTON DRUMMOND, R.A.M.C. (T.)

(A Report to the Medical Research Committee.)

It is, we believe, common experience, that wounds of the colon caused by missiles which perforate the viscus, differ little in character from the lesions so produced in the small intestine. If they are seen early, and closed by appropriate methods, they may be expected to heal readily and give satisfactory results if unassociated with other serious complications. The lesions of the colon which we propose to describe in this paper differ markedly from such direct wounds, not only in respect of their causation, but also as regards immediate and ultimate prognosis. We have observed that where a missile has passed near to a fixed portion of the colon, without actually touching its wall, it may give rise to an appearance of extensive ulceration of the colic mucous membrane. This form of ulceration is very liable to extend deeply into the intestinal wall, and to be followed by perforation and peritonitis or retroperitoneal cellulitis. The condition is therefore, of itself, a very grave form of injury, and may frequently prove fatal apart from the effects of other lesions which may accompany it. There is little doubt, however, that ulceration of this type is sometimes present in cases which ultimately recover. We have had opportunities of observing it only at very early dates after wounding, and only in cases which proved fatal; but it has not always been the direct cause of death. Further, we have been informed by General Sir Anthony Bowlby that fæcal fistula is a not infrequent late development in relation to wounds of the loin which are known not to have penetrated the intestine. It seems very probable that the condition we describe will afford an adequate explanation of an occurrence of this kind.

Case 1.—S., age 30, was wounded at 2 a.m. on June 30, 1916, and admitted to hospital twelve hours later. When seen, he was suffering severely from shock; there was general rigidity of the abdominal wall, and marked tenderness over the lower half of the abdomen. A small round wound of entry was found in the left loin, just above the iliac crest, and four inches behind the anterior spine. The exit wound, also on the left side, was at a point half an inch above the middle of Poupart's ligament.

At operation, twenty hours after wounding, the descending colon was exposed through an oblique incision in the left loin, parallel to the track of the missile. No perforating wound was observed on the colon, but two areas of hæmorrhage were present on its wall, one at the level of the entry wound, and the other an inch and a half lower down. The lower of these bruises, which extended circularly round the bowel, was much blackened, and there appeared to be commencing gangrene,

involving the peritoneal coat. This damaged area was covered in by Lembert sutures, and the wound was drained. The general condition of the patient was very bad, and death occurred shortly after operation.

FIG. 20.—Ulcerated portion of descending colon in *Case* 1. The ulcers tend to encircle the wall of the viscus. Their bases are formed by submucous tissue, containing much blood.

The outward appearance of the descending colon was as seen at operation, but a third area of bruising was noted two inches below the lower of those previously mentioned. The track of the missile was mainly extraperitoneal, and not directly against the colon; there was certainly no gross laceration of the outer wall of the viscus. On opening this portion of the colon, three areas of ulceration were found on the mucous membrane, corresponding in position to the zones of hæmorrhage seen externally. The ulcers, which were fairly extensive (*Fig.* 20), tended to be annular in shape; but only the uppermost of them encircled the lumen completely. They penetrated into the submucous layer, but not through it. The bases of the ulcers were black with altered blood, and appeared to be gangrenous. By careful dissection, the mucous and submucous coats, with the ulcers, could be stripped from the muscular layer. The separation was effected with particular ease in the regions of the ulcers, where slight hæmorrhage had taken place between the layers. Many of the minute blood-vessels perforating from the muscular to the submucous coat had evidently been torn across in these areas. Underneath each ulcer there was some damage of the circular layer of muscular fibres, but this was of slight extent compared with the lesions in the mucous membrane. It consisted of short linear tears, running across the muscular fibres (*Fig.* 21): the lesions occurred in the sacculi, between the longitudinal muscular bands.

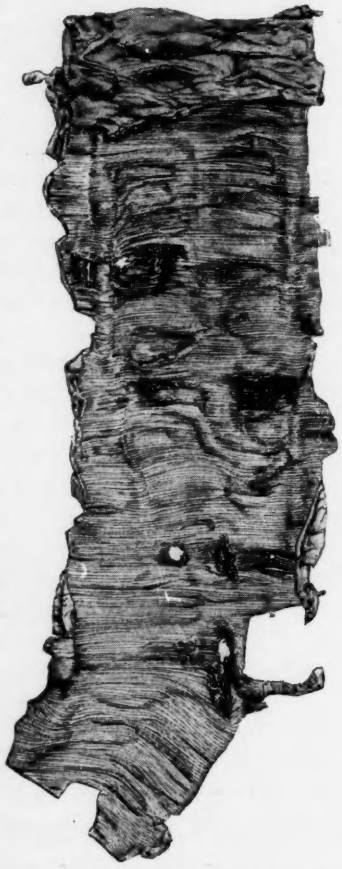

FIG. 21.—Musculature of wall of descending colon in *Case* 1, underlying the ulcerated areas. Some laceration of the circular fibres is visible at places which coincide with the points of deepest ulceration. The longitudinal bands of muscle are intact in this case. Note indication of hæmorrhage around the lacerations.

Case 2.—D. was wounded by a rifle bullet at 11.30 p.m. on Sept. 9, 1916, and was admitted to hospital five hours later, in a condition of shock. A small round wound of entry was found in the middle line of the back, at the level of the fourth lumbar spine. The exit wound, which was much larger, measuring one and a half inches across, was in the left

mid-axillary line, at the level of the tenth rib. A loop of the transverse colon, with a portion of great omentum, was prolapsed through the latter wound.

At operation, six hours after wounding, the condition of the abdomen was examined through a mesial incision. There was no visible lesion of the transverse colon, either inside the abdomen or on the extruded portion, but a circular band of hæmorrhage, associated with an appearance of early gangrene, was observed on the wall of the descending colon just below the splenic flexure. This damaged portion of descending colon was drawn out posteriorly through a small left flank incision. Death occurred twenty-six hours after operation.

There was slight early general peritonitis. The bullet track was found to pass forwards and to the left through the deep muscles of the back, behind the descending colon, and through the posterior edge of the spleen. Thence it passed through the diaphragm at its costal attachments, and through the ninth and tenth ribs, portions of which, one to one and a half inches in length, were missing. There was no ulceration in the portion of transverse colon which had prolapsed. On the other hand, at the level of the annular zone of bleeding in the muscular coat, there was a patch of ulceration on the outer and anterior aspect of the bowel. The ulcer was of hour-glass shape, its two segments lying over sacculi, and the isthmus over the external longitudinal band. The base of the ulcer, which was formed by gangrenous submucous tissue, was black with hæmorrhage. On dissecting off the mucous and submucous coats, two irregular lacerations were found in the circular muscular fibres which underlay the broad parts of the ulcer. The penetrating vessels to the mucous coat had been torn in these areas. The lesions in the muscular coat were of small extent compared with those in the mucosa.

Case 3.—M., age 21, died seven hours after being wounded by a rifle bullet which traversed the abdomen from right to left.

It was found that the track passed through retroperitoneal tissue, below the lower pole of the right kidney, and into the body of the third lumbar vertebra, which was comminuted. The missile had thence passed forwards through the left side of the peritoneal cavity, wounding directly the transverse colon and a loop of jejunum, and had made its exit through the anterior abdominal wall. There was no direct wound of the descending colon, but there was much bleeding under its peritoneal coat, and in the retroperitoneal tissue. The hæmorrhage in the wall of the colon was irregularly distributed along four inches of the bowel. This portion of descending colon, when laid open, presented several large areas of ulceration of the mucous membrane. The ulcers were irregular in shape, and the depth to which they penetrated varied in different parts. They were deepest, reaching the muscular coat, in the sacculi between longitudinal bands. The mucous membrane and submucous coat were dissected off from the muscular layer. It was then seen that beneath the areas of hæmorrhagic ulceration there was slight bleeding on the surface of the circular muscular coat. The separation of the layers could be effected with great readiness in these areas, and many of the small blood-vessels perforating from muscularis to submucosa had evidently been torn across. Several lacerations of fibres were found in the circular muscular coat under the deepest parts of the ulcers. The lacerations extended across the fibres, in the long axis of the intestine, and they were situated in the unsupported sacculi. No portion of muscular tissue had been actually torn away. Microscopic examination of two of the ulcerated areas showed tearing of circular fibres, and hæmorrhage between the torn ends.

Case 4.—W., age 21, had received multiple grenade wounds at 4 p.m. on Oct. 27, 1916, and he was admitted to hospital at 7 p.m. on the same day. When seen on admission, he was suffering severely from shock, the pulse being 140 per minute. The abdomen was very rigid and retracted, and showed scarcely any respiratory movement. Two small entry wounds were found on the anterior wall of the abdomen; one of these was two inches above the left anterior superior iliac spine, and the other about an inch to the left of the first, at a slightly higher level; a tag of omentum projected from the latter wound. There were other severe wounds on the limbs.

Laparotomy was performed in the middle line. A large perforating wound was

found in the pelvic colon, and another in the upper part of the jejunum. The latter wound necessitated resection, while that in the pelvic colon was brought out through a separate incision in the left flank, as a colostomy. The tracks of the two missiles were seen to pass into the posterior abdominal wall, one on either side of the descending colon. The wall of that viscus showed some hæmorrhage opposite the level of these wounds, but there was no perforation, and no evidence of direct damage. Death occurred five hours after the operation.

It was confirmed that there had been no direct injury of the descending colon by either missile : the missiles, two portions of rifle-grenade, were found embedded in the muscles of the posterior abdominal wall. The descending colon, when slit open, showed an area of ulceration an inch in diameter, towards its anterior aspect, at the level of the hæmorrhage seen externally. The ulcer was of irregular outline, and its base was infiltrated by blackened blood. This ulcer, when examined microscopically, was seen to be associated with tearing of the circular coat of muscular fibres. Much hæmorrhage was present in the submucous tissue, and in the fissures in the muscular layers.

FIG. 22.—Mucous surface of caput cæcum and part of ascending colon in *Case* 5. There are three fairly extensive ulcers on the posterior wall, one being in the caput. The base of each ulcer is formed by the submucous layer, and is much infiltrated with blood.

Case 5.—G. was wounded by a rifle bullet at 11.30 p.m. on June 17, 1916, and was admitted to hospital six hours later, much collapsed. A small round entry wound was present in the left buttock, and the exit wound, which was larger and irregular, was in the right mid-axillary line at the level of the costal margin.

Laparotomy was performed shortly after admission. There was no evidence of injury of the abdominal viscera, except some hæmorrhage on the wall of the cæcum and behind the peritoneum of the right flank. Some blood-stained urine was passed a few hours later. Death occurred twenty-one hours after wounding.

It was found that the wound-track passed from the left buttock through the sacro-sciatic notch and the upper part of the sacrum, through the belly of the right psoas muscle, and thence between the right kidney and the ascending colon. Neither of the latter viscera had been directly touched ; a layer of retro-peritoneal fat a quarter of an inch in thickness intervened between the track and the colon wall. There was cellulitis and gangrene around the wound-track in the retroperitoneal tissue, and films and cultures made later from this material showed abundant gas-forming, anaerobic bacilli. The capsule of the right kidney was intact, but two subcapsular lacerations were present in the cortex on the anterior aspect of the lower pole. The ascending colon exhibited externally only some hæmorrhage on its inner side. When this portion of bowel was opened, two large areas of ulceration were observed on the posterior wall, while a third was seen in the caput cæcum (*Fig.* 22). The two uppermost ulcers lay almost directly over the bullet track. Each ulcer

penetrated deeply into the submucous coat, but not quite through it ; the bases were necrotic, and dark with hæmorrhage. The mucosa and submucosa were then dissected off from the muscular layers. By this means it was shown (*Fig.* 23) that underneath the middle and uppermost ulcers the posterior longitudinal band of muscle had been sharply torn across. The torn ends were widely retracted, and the circular fibres, though not lacerated, were drawn apart with them, so as to leave a complete wide gap in the muscular layers. Each of these lesions was associated with some hæmorrhage, and the exposed retroperitoneal tissue was foul and gangrenous. A like muscular lesion was also observed in the outer longitudinal band, opposite the level of the upper ulcer, but it was unaccompanied by hæmorrhage or by ulceration of the mucosa. In relation to the ulcer in the caput cæcum, there was only slight tearing of the circular fibres, with some hæmorrhage.

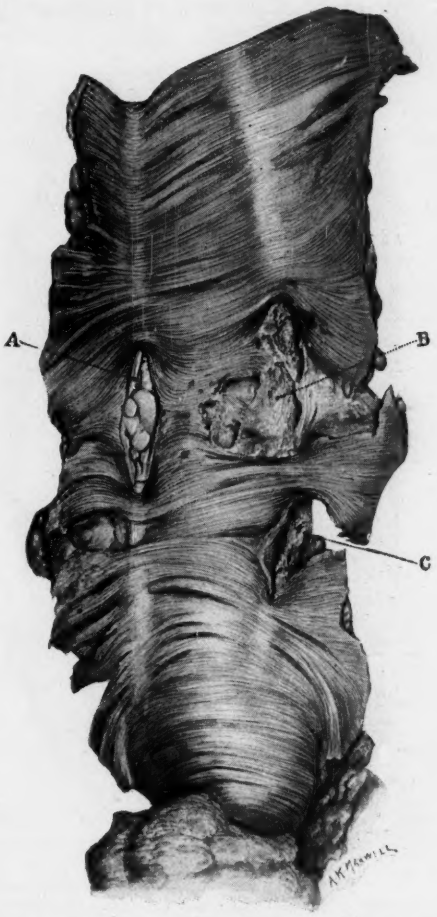

FIG. 23.—The muscular wall of the colon underlying the ulcers shown in *Fig.* 22. The posterior longitudinal band of muscle is torn across in two places (B and C), and the torn ends have retracted, drawing with them the fibres of the circular layer. It is seen that these lesions in the muscle correspond exactly in site with the two ulcers in the ascending colon The tear in the outer longitudinal band, marked A, was unassociated with ulceration. The arrangement of the muscular lesions in this case affords good evidence that they were produced by indirect violence, as all of them were caused by one rifle bullet.

Case 6.—B. was struck by a piece of shell in the region of the right buttock at 5 a.m. on Sept. 11, 1916. He was admitted to hospital in a condition of extreme collapse, and died thirteen hours after receipt of injury.

An entry wound, the size of a half-crown, was present on the right buttock over the great sacro-sciatic notch ; the exit wound, much larger, centred round the site of the right sacro-iliac joint. The greater part of the right side of the sacrum, and the posterior end of the iliac blade, had been carried away by the missile. The perirectal adipose tissue, which was exposed in the wound, was not actually lacerated, but exhibited much diffuse hæmorrhage over an area two inches in diameter. The appearance of the tissue indicated commencing gangrene. The rectum was removed, and opened from the front. A large and deep ulcer was found on its posterior wall corresponding in site to the hæmorrhage seen posteriorly. The lesion measured two and a half inches across and one and three-quarter inches in length, and had a hæmorrhagic, gangrenous base composed of perirectal adipose tissue (*Fig.* 24). Two areas of superficial ulceration, associated with hæmorrhage, were present on the rectal mucosa at a lower level. The appearance of the large lesion was very suggestive of the actual loss of a large portion of the muscular and mucous coats, but in view of the fact that the injury took place only thirteen hours earlier, it is apparent that the gap must be explained by the retraction of torn edges of tissue. The tear was evidently not produced by immediate contact of the missile, for behind it the layer of adipose tissue was three-eighths of an inch in thickness. The superior hæmorrhoidal artery was traced downwards through

this tissue to its finer branches. The wall of the vessel showed some hæmorrhagic staining, but no actual rupture.

The feature which attracted attention in this group of six cases was the appearance of extensive ulceration of the intestinal mucous membrane, where the external aspect of the bowel had not given rise to suspicion that such a condition existed. These lesions were fully developed at remarkably early periods—from seven to twenty-six hours—after receipt of the causal injuries. In each case it could readily be ascertained that the ulceration had arisen in relation to the passage of a missile which did not perforate the viscus, or even come into direct contact with its wall.

FIG. 24.—Ulceration or laceration of wall of rectum in *Case* 6. This condition was observed fifteen hours after wounding by a piece of shell. The missile destroyed a great part of the sacrum, but did not actually lacerate the retroproctal adipose tissue. The superior hæmorrhoidal artery could be traced to its finer branches. The gap in the mucous and muscular coats had thus been produced by transmitted violence.

In explanation of the lesions, two main facts have been observed by dissection. First, there was always some laceration of the muscular coats, though this was usually very slight in extent compared with the lesion in the mucosa, and it was not associated with actual loss of muscular substance. In one instance (*Case* 5), the damage to the muscular layers had clearly been produced by a dragging effect transmitted through strands of fibrous tissue or blood-vessels: in this case there was also deep laceration in the cortex of the kidney, though the capsule was intact. In the other cases, the effects were most probably due to sudden impact on a gas-filled sac, resulting in bursting at weak points. The lacerations here occurred most commonly in the unsupported sacculi; evidence has previously been brought forward by one of us to show that in the normal sacculi there are specially weak points where the larger vessels perforate the muscular wall to reach the mucous membrane.[1] In referring to the damage to the muscular coats, it seems important to note that the lesions have been observed only in fixed portions of the colon, and never in the freer parts supplied with a mesocolon, or in the small intestine.

The other fact of interest was that many of the perforating vessels to the mucosa in the damaged areas were torn across at the points where they passed from the muscular into the submucous coats. This afforded an explanation

of the great extent of loss of mucous membrane where the injury of muscle was comparatively trivial: the patch of mucosa had really been killed by loss of blood-supply.

In all cases it was apparent that the damaged tissues were subjected to early infection from the lumen of the bowel, and readily became gangrenous: at later dates the loss of tissue from this cause would no doubt have been much greater.

From the point of view of treatment, it is evidently important to provide adequate drainage of wounds in the flanks in all cases where definite bruising is visible on the wall of the colon; this applies particularly to the fixed ascending and descending parts.

REFERENCE.

[1] DRUMMOND, *Brit. Jour. Surg.*, 1917, iv, No. 15, 407.

THE EARLY TREATMENT OF GUNSHOT FRACTURES OF THE THIGH.

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After two and a half years of war, surgical opinion as to the most satisfactory method of treating compound fractures of the femur is by no means unanimous. One school, following Lieutenant-Colonel Robert Jones,[1] maintains that the best results can be obtained in general by a 'fixed' long-axis pull with the limb in a position of extension. Another school, of which Major Hey Groves[2] is the champion, contends, as did the old surgeons, that true alinement cannot be obtained when the limb is extended at both knee and hip, and that the position of the double inclined plane is the correct one; moreover, continuous weight extension is favoured, as opposed to fixation in extension.

The procedure of plating gunshot fractures, at any stage, except as a very exceptional measure, has fallen into the disrepute the results justify.

In the course of our experience in this war we have treated fractures in accordance with both the above-mentioned principles. For the purposes of *transport*, there can be no question that the Thomas knee splint, or one of its modifications, is the best arrangement available. On account of its extreme value in this respect, and for its convenience in wound treatment, there has been a tendency to perpetuate its use in the classical form for the late treatment of unsuitable cases. From our observations we are firmly convinced that in fractures in the lower third of the femur, the commonly occurring flexion of the lower fragment is seldom, if ever, completely controlled by a straight Thomas knee splint. For these cases we have used the Thomas splint, but bent at the knee level, thus obtaining a skeleton inclined plane. By the use of this method our results have been much improved, as far as alinement is concerned.

We propose here to deal with the practical treatment of gunshot fractures of the thigh in the period during which wound treatment and proper apposition of the bone fragments are the chief problems. We also deal, as far as our experience permits us, with the measures which, adopted at this stage, assist the restoration of function.

Our conclusions are drawn from observations on 198 cases. Systematic notes on the forms furnished by the National Research Committee have been kept on the last consecutive 125 of these cases, and statements in this article are based on the latter group. Cases of gross injury to the knee or hip-joint have not been included in the series, nor those cases in which immediate amputation was undertaken for spreading gas gangrene.

We have throughout used splints and material of standard pattern, and such as are issued from the Army Medical Stores.

The following statistical statement gives a general outline of the cases dealt with :—

Total number of cases	125
Fracture in subtrochanteric area	26
,, upper third of femur	21
,, middle third	30
,, lower third	44
,, supracondylar area	7
,, both limbs	3
Cases not infected	10
,, of mild infection	16
,, medium infection	28
,, severe infection	71
Average period between injury and observation	78·8 hours
,, ,, of observation of cases ..	51·5 days
Average amount of shortening on transfer ..	0·378 inch
Number of amputations	4
Number of deaths	10

'*Concussion*' *Fractures.*—In this series, 13 cases showed fractures, on *x* ray examination, either oblique or of the 'flûte en bec' type, with little or no comminution at the seat of injury. In these cases the missile lodged, generally, near the bone, though in two instances it appeared to have no relation to the latter. Infection of the wound was present in all instances, and was classified as mild in 5, moderate in 5, and severe in 3. In no case did signs of severe bone infection ensue.

This type of fracture is presumably due to the local concussion action of a slow-travelling missile. In general, the prognosis for this class of fracture is better than in the cases in which the bone has been perforated and comminuted.

Our aim has been to keep every case under observation till any infective process has been reduced to a minimum, and till union has commenced in good line and without undue shortening.

The final functional results we have only been able to observe in a few cases, though we have received reports from home hospitals of the after-course of a fair number.

WOUND TREATMENT.

As might be expected, in the course of dealing with an extended series of cases, the method of wound treatment has varied with the ideas of the time. As the full discussion of this complicated subject is beyond the scope of this paper, we will merely state our views of it in dogmatic form, and attempt to define what we conclude to be the ideal procedure in these cases.

Primary Operative Procedure.—In all cases satisfactory drainage should be established once and for all at the earliest possible moment after the injury. Repeated anæsthetics and operations during the early period are to be deprecated in the treatment of these cases. The necessary procedure should therefore be effected at the casualty clearing station, where in any

case the patient is anæsthetized for cleaning up and the application of a splint. If practicable, the surface of the whole wound track should be excised; excision or incision of the skin wounds alone is a useless procedure. All fragments of bone lying loose should be removed; if left, they are a frequent source of persistent local infection: and there appears to be no doubt that so long as the periosteum is not unduly damaged, perfect union results, despite the loss of considerable amounts of compact bone. We prefer to pack the wounds so treated with dry sterile gauze. In the earlier cases of the series we employed tube drainage down to the bone from the posterior wound, but the limitation of infection seems to be better effected with the simple gauze pack. If the original wound or wounds do not furnish posterior drainage, a four-inch incision should be made on the postero-external aspect of the limb, and access gained to the seat of fracture along the line of cleavage between the outer hamstrings and the vastus externus: a part of the latter will have to be cut away in order to make the opening a free one.

Routine Dressing.—The primary gauze pack should be left undisturbed for two or three days, in the absence of signs of spreading infection; it should be removed and lightly renewed at intervals for a week or so; at the end of this period, in favourable cases, no further mechanism to keep the wound open will be necessary. A tube drain through the posterior hole down to the bone should be employed when there is evidence of continued osteitis and retention of discharge. In these latter cases a considerable saving in outside dressings may be frequently effected by passing the tube between two support slings and allowing the discharge to drip into a porringer. The outside dressings should be changed every twenty-four hours while acute infection is still active. During all processes the limb should be moved as little as possible, and it should never be necessary to roll the patient on his side for any purpose.

Spreading cellulitis of streptococcal origin, arising as it commonly does soon after the injury, is best left to take its own course, assuming that proper drainage has been established in the first place. Further incisions at this stage hinder rather than assist the patient's natural defence.

We have seen no case of *erysipelas* at this stage, though it occurred sporadically in four cases after sequestrectomies, and then pursued a usual course.

The *Bacillus aerogenes capsulatus* is present in many cases of severe infection, but it does not lead to progressive necrosis and toxæmia in those in which the wounds have been laid open in good time. If gas formation occurs in such an open wound, and no severe toxæmia is present, the case should be left quiet, and the wound will rapidly clean up. When spreading gangrene occurs, free incisions may suffice to arrest the process; if there are signs of severe toxæmia, amputation will be the only course. Local excision of the necrotic area in this class of case does not seem to be practicable so frequently as in lesions in the lower part of the leg.

SPLINTS.

The treatment of infective gunshot fractures may be roughly divided into three periods, in each of which the splint problem varies slightly. These are: (1) The period of early transport; (2) The period of acute infection; (3) The period of healing.

1. *The Period of Transport.*—The Thomas knee splint is the best available appliance. It is easily packed and handled, and is simply applied. It affords means of efficient self-contained extension, and allows of free access to all wounds. Moreover, it is sufficiently efficient even when the ring does not fit.

For those cases in which the presence of a wound about the hip-joint prevents the application of a Thomas splint, a Liston long outside splint, or some modification of it, is most suitable. It is not easily applied efficiently, on account of the difficulty in fixing it firmly to the pelvis, and it is not convenient for wound treatment.

2. *The Period of Acute Infection.*—The Thomas knee splint is suitable for all fractures occurring in the lower two-thirds of the bone. It secures the necessary immobilization under moderate extension, and affords free access to the wounds. For all fractures in the upper third, the Hodgen splint is well suited at this stage.

3. *The Period of Healing.*—This may be regarded as commencing in the second or third week. The chief object is to secure proper position of the bone fragments. In the lower third of the bone we use the Thomas splint in a modified form; the leg is pulled out to full or over length, and then, generally under anæsthesia, put up in flexion in the same splint bent at the knee level. Fractures in the middle third can readily be controlled in the classical form of the Thomas splint. For the upper third we use the Hodgen splint in general; in some cases, however, it is difficult to maintain sufficient flexion at the hip to secure good alinement, and other measures must be adopted.

Details of the Thomas Knee Splint.—The proper action of this splint depends on a close fit of the ring, so that the upper *point d'appui* shall be the ischial tuberosity. For average cases, rings with an internal circumference of 23 to 26 inches secure this condition. The impositions of active service have as yet made it impossible to secure a fit in the majority of cases, and we have commonly used splints with an inside diameter of 27 inches or more; such splints take purchase in the main on the bones of the ischio-sacral angle, and though not so comfortable as the correct pattern, they allow of full extension being made. To all these splints we add a prop of aluminium. This prop (see *Fig.* 25) should be wide based, and placed at least six inches up from the foot level, so that there is no risk of its slipping over the edge of a stretcher. The malleable nature of the prop allows of its being adapted to the slope of the stretcher when necessary; if made of iron, an adjustment for this purpose should be provided. A foot-supporting arch may be added in some cases, but we prefer a balanced foot suspension, for reasons given below.

Modifications of the Thomas Splint.—The best known of these is the Wallace-Maybury splint. In our opinion this splint possesses no advantages over the original pattern, and has certain definite shortcomings. It is expensive and cumbersome. The side bars are so massive that no bending of them is practicable. The rectangular fixed position of the foot which the splint imposes is unsatisfactory, for the following reasons: (1) The right-angled position of the foot increases the tension on the gastrocnemii, and so

tends to increase any flexion of the lower fragment; (2) The fixation of the foot impedes the maintenance of function in the lower part of the leg during treatment.

Another modification was introduced by one of us (C. M. P.).[7] It is made from the standard aluminium splinting, and was designed for transport. Its malleable crutch makes it serviceable for this purpose, and the prop is a useful feature. For continued treatment the splint is not sufficiently rigid to procure full extension in any but light cases.

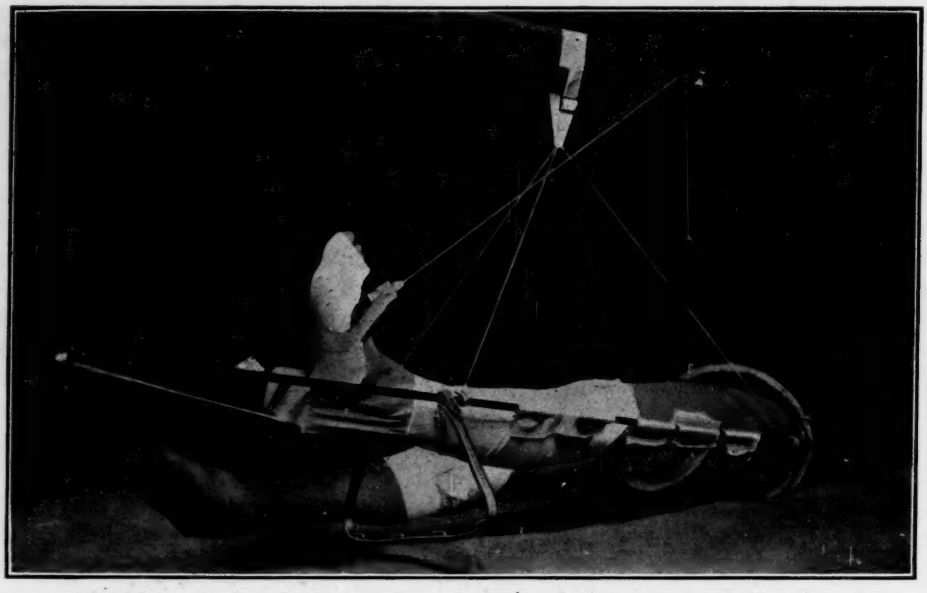


FIG. 25.—Thomas knee splint applied, and suspended from a beam. A moulded plaster foot-piece, with balance, for cases of foot-drop, is also shown.

Details of the Hodgen Splint.—We employ the standard pattern of this splint, but do not use the original form of suspension and extension. The splint is hung from a Balkan beam (*Fig.* 26), from two adjustable levels. Extension is applied by a weight attached to the end of the splint, the attachment running over a pulley in the upright of the beam. This method has been described by Stimson[3] and Hey Groves.[8]

Details of Extension Attachment.—For both of the above-described splints we commonly use an extension attachment of the Buck type. The application is made with ordinary adhesive strapping, or by means of Heusner's glue applied to fine cotton bandaging. The latter adhesive consists of:—

Methylated spirit	50 c.c.
Benzine	25 c.c.
Resin (commercial)	50 grms.
Venice turpentine	5 grms.

We prefer to use ordinary adhesive strapping, as it seems less inclined to produce vesication of the skin, and when it does give way, does so gradually

and not with the completeness which is characteristic of the glue application. A stirrup or spreader wide enough to prevent pressure on the malleoli is set in the foot end of the extension unit.

Transfixion of the bone for extension purposes has a strong advocate in Major Hey Groves. The advantage common to the method in all situations is the ease with which full extension may be effected. In cases where the lower fragment of the femur can be transfixed, the method has the further advantage that the knee-joint is left free from pull or fixation, and the lower fragment can be suspended in any position. We have used transfixion pins in several cases where it was impossible to apply a Buck extension, or where a fuller control of the lower fragment of the femur was required. For the femur we

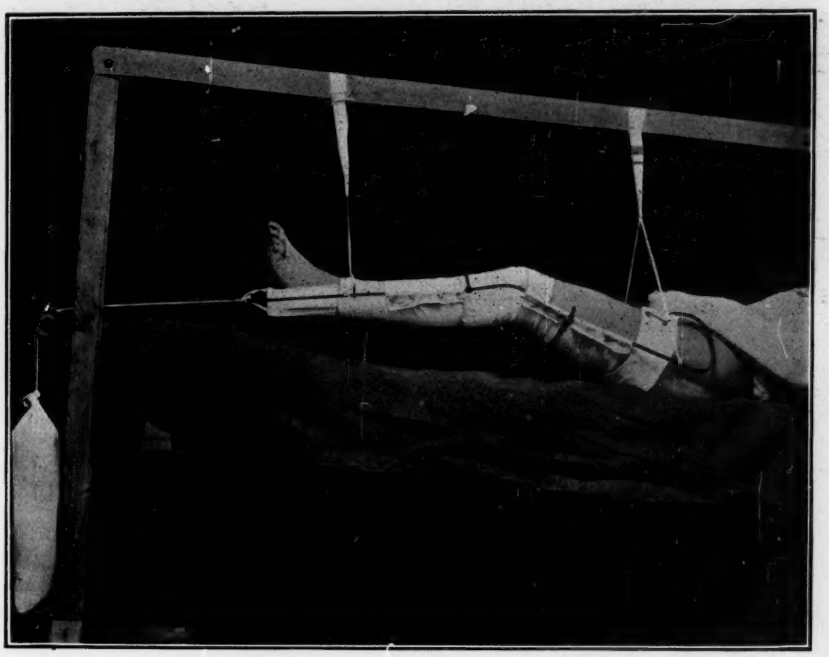


FIG. 26.—Method of suspension and applying extension in the case of a Hodgen splint.

use pointed steel pins 4 mm. in diameter, and for the os calcis similar pins 3 mm. in diameter. The pins can be readily made from steel knitting-needles of the appropriate size. In the absence of a proper drill, we hammer the nails into place, according to Wilms'[4] technique. A horseshoe bent from aluminium splinting affords the coupling for the extension, as shown in *Fig.* 27. The risk of infection has always to be borne in mind in using this method, and we do not consider it a suitable one for conditions of active service, save in exceptional cases.

Anklet extension attachments have not proved a success. We have used moulded plaster-of-Paris anklets, and also the usual leather type, and —especially with the latter—have found that sores over prominences are rapidly formed if any degree of extension is exerted.

Application of Splints.—The skeleton splints described are completed by slings. We prefer old linen for this purpose above anything; it does not stretch, and yet is easily adaptable to the contour of the limb; it is absorbent, and not irritating to the skin. Flannel has its uses for this purpose, but stretches too readily to be of full service in the healing period. Enough slings should always be used to support as completely as possible the posterior surface of the limb; they should be so arranged about the fracture, that when the dressing slings are removed, both fragments are still held in place by others. Zinc troughs in place of slings do not appear to have much to recommend them; unless they are very carefully applied they are liable to cut the skin

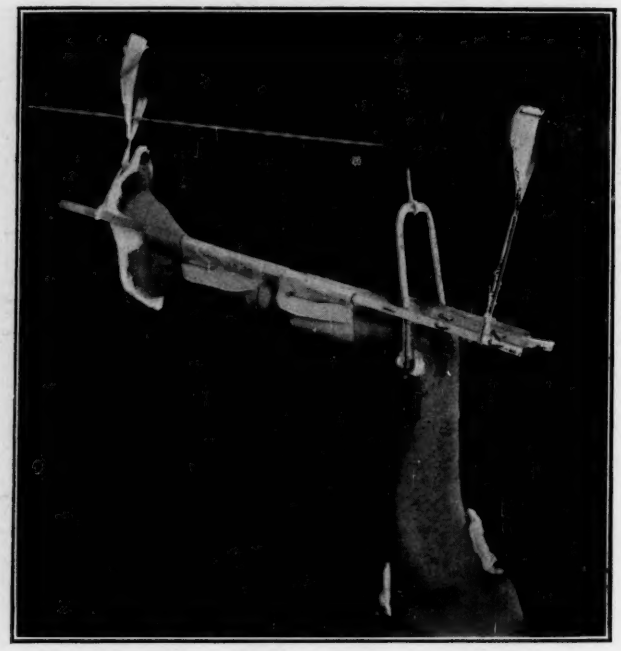


FIG. 27.—Transfixion of lower end of femur in a case of subtrochanteric fracture, and suspension with a weight of 20 lb. at a right angle.

at their margins; moreover, they render the posterior surface of the thigh inaccessible.

The extension is attached to the splint by a strap passing over the notch in the splint and the stirrup of the extension (see *Fig.* 28). This method gives a simple extension which is easily regulated. We consider the method of tying the extension strips round the end of the splint, advocated by Lieutenant-Colonel Jones,[1] to be unsatisfactory for gunshot fractures; in our experience it has not been possible or even desirable to obtain full extension at the time the splint is first applied. If this is admitted, some adjustable form of attachment must be supplied, and the strap system answers the purpose as efficiently as the more elaborate and slower acting screw arrangements.

After-Treatment.—During stationary treatment, the Thomas splint, as well as the Hodgen, should be suspended from a beam (*Fig.* 28). This allows more freedom to the patient, and facilitates nursing and dressing.

The maintenance of extension presents no difficulties in the case of the Hodgen splint. In the case of the Thomas, the so-called 'fixed extension' is really an elastic pull, owing to the resilience of the tissues covering the *point d'appui*, and the elasticity of the skin to which the extension is attached. This extension is kept up by tightening the strap as necessary, and in most cases the limb can be so pulled out to full length or over. Failure in this respect is usually due to intolerance on the part of the patient to the continued

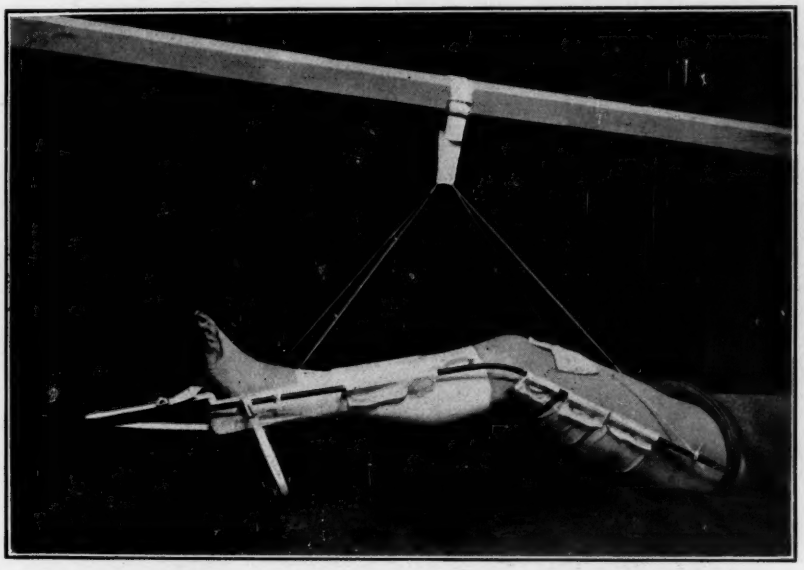


FIG. 28.—A Thomas knee splint bent at the knee level for a case of fracture in the lower third of the femur. The method of strap attachment of the fixed extension is well shown.

counter-pressure. In such cases, or if a sore forms over the ischium, weight extension may be attached to the lower end of the splint, as is done in the Hodgen splint. This form of extension can be continued to the end of treatment or not, as may be convenient.

Pressure sores should not develop under the ring of the Thomas splint if the parts exposed to pressure are cleaned with spirit, powdered, and gently rubbed twice daily. It should be remembered that such sores in any part are most readily formed soon after the application of a splint, before the skin and subcutaneous tissues have adapted themselves to the new arrangements. In early transport, therefore, powerful extension should not be applied, and any complaint of the patient as to pressure should be carefully attended to.

Position of the Foot.—In both the above-described splints, if there is no paralysis, the foot should be allowed to lie in the natural position, i.e., slightly everted and plantar flexed. The patient should be encouraged to move the

foot at intervals. If the foot is left in this way, foot-drop does not develop, and union of the fragments will occur in the normal position without the inversion which is often seen in cases in which the foot has been fixed at a right-angle. It should be remembered that after a fracture below the trochanter, the upper fragment is maintained in the everted position by the action of the glutei.

Control of Foot-drop.—Some degree of paralysis of the anterior tibial group was present in 17 of the cases in our series. The best method of control seems to be to apply a plaster cast to the sole of the foot (*Fig.* 25); the toes are thus kept in position, and the whole foot is balanced by a small counter-weight acting over a pulley on the beam. This method allows of active movement at the ankle, while normally maintaining the paralyzed muscles in a lax position. Fixation of the foot to an arch or foot-board attached to the splint is not so satisfactory for prolonged treatment.

CONTROL OF BONE FRAGMENTS.

For the first week or two, in severely infected cases, the limb should rest comfortably, and no forcible effort be made to pull it out to full length; strong long-axis extension increases the tension in the aponeurotic sheath of the thigh, and so prejudices the course of the natural reaction to the infective

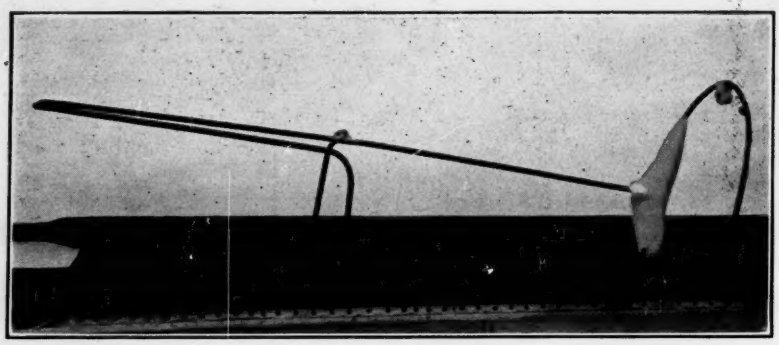


FIG. 29.—Carrier for a Hodgen splint. This has been made from a large-ringed Thomas knee splint.

process. In clean cases, or in those mildly infected, the bones should be brought into their proper position in the first week of treatment.

An x-ray examination is required before a deliberate attempt is made to aline the fragments truly. Plates taken in two planes at right angles are necessary. This is difficult to achieve in the upper third, and one may have to trust to a stereoscopic view. Captain J. N. Ferguson has taken some excellent plates for us, however, getting a lateral view of the upper part of the bone by flexing the thigh of the uninjured side, placing the plate to the outer side of the injured limb, and taking the picture from inside and below

In order to overcome the difficulty of taking *x* rays of patients in Hodgen's splints, we have devised a carrier (*Fig.* 29), which slings the splint in

its usual position and maintains extension. It is made from a large ringed Thomas knee splint. A carrier is required for each side. To form the carrier, the outer bar of the Thomas is cut away from the ring, and bent so as to form a wide-based high prop at about mid-leg level; the free extremity of the prop is bound to the inner bar. The ring is cut through behind, and bent so as to form an arch which passes around and above the upper extremity of the Hodgen splint. To prepare the patient for transport, the upper arch of the Hodgen is suspended from the central part of the carrier arch. The lower part of the Hodgen rests on the narrower extremity of the carrier (*Fig.* 30). A strap is then passed round the end of the Hodgen and the notch in the carrier, and tightened till the 'fixed extension' so effected equals the weight extension, the upper *point d'appui* being formed by the inner leg of the arch of the carrier abutting on the perineum. The weight is then detached from the Hodgen splint, and the patient is ready for removal.

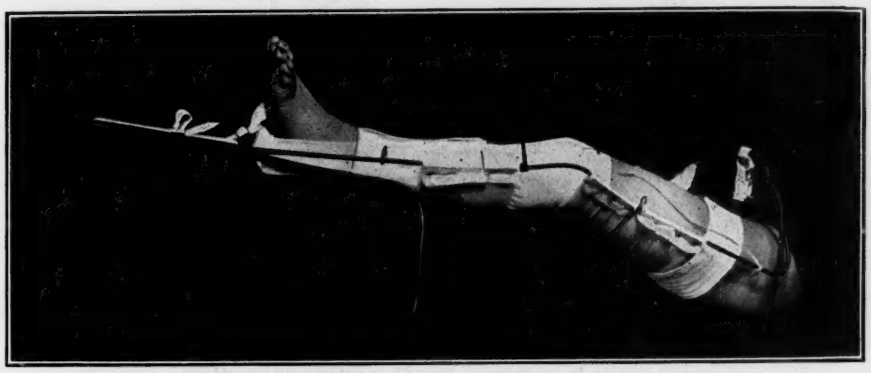


FIG. 30.—The Hodgen carrier in use. The splint is suspended from the arch of the carrier above, and rests on the lower part. 'Fixed' extension is effected by means of a strap, the inner limb of the arch of the carrier exerting counter-pressure in the perineum.

Measurement of the limb is important, but it does not reveal flexural displacements of the fragments.

Principles Determining the Reduction of Displacement of Fragments.—Long-axis traction is undoubtedly the main factor which determines the return of the fragments to their natural position. Its first action is to disentangle the ends of the fragments from the surrounding tissues, and to draw the ends apart so that they can move independently of one another. Its second action is to increase the tension within the fascial sheath of the limb; the tension produces a circumferential force acting on the freed bone ends, and tends to push them back into their normal place, where they occupy the least space.

The displacement of the fragments is due to: (1) The force of impact of the missile; (2) The forces acting as the patient falls; (3) The tonic action of muscles on the fragments after the normal balance of muscular action has been destroyed by the loss in skeleton continuity.

The displacement due to the first two causes is controlled once the bone ends are disentangled by long-axis traction. That due to muscle tone will

continue to produce a certain displacement, unless: (*a*) A sufficient reducing force can be applied, either through tension produced by long-axis traction, or by the direct action of pads acting from an outside mechanism; (*b*) The joint on which the muscle acts is so placed that the latter becomes completely relaxed.

In dealing with the *lower half* of the femur, flexion of the lower fragment (except in impacted cases) is constantly observed; the muscles, acting unopposed, which produce the displacement being the gastrocnemii and short

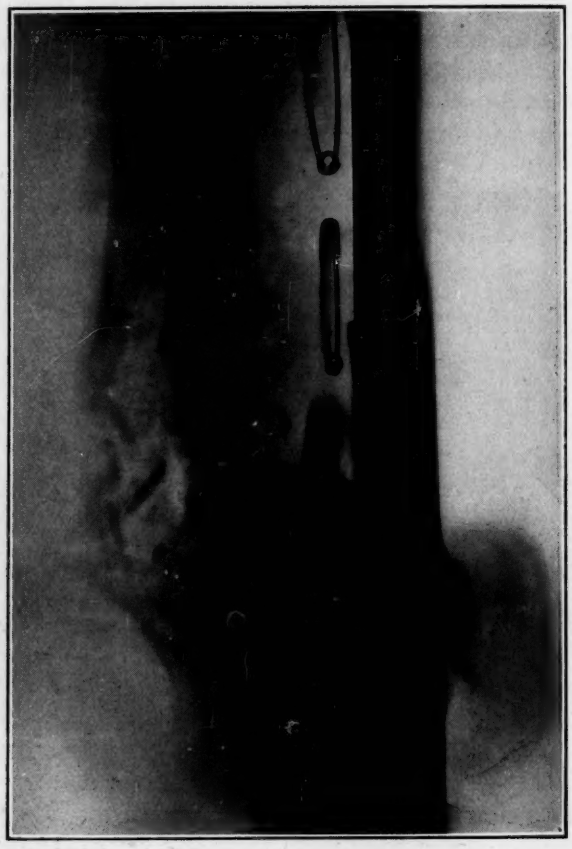


FIG. 31.—Showing the extreme flexion of the lower fragment in a supracondylar fracture. Long-axis extension failed to effect replacement.

head of the biceps. If the fracture be towards the middle of the bone, the reducing forces will be acting as a long lever against the muscle tone, and so reduction of the displacement is easily effected; in practice, the use of the Thomas knee splint gives excellent alinement in the middle third fractures. As the fracture gets nearer and nearer the condyles, so the leverage through which the reducing force acts diminishes, till, in a true supracondylar fracture, the lower fragment may be sharply flexed (*Fig.* 31) and no degree of long-axis traction will have any reducing effect upon it.

The same principles apply to displacements in the *upper half* of the femur. The almost constant displacement in the upper third is flexion due to the unopposed action of the ilio-psoas, and abduction and external rotation caused by the gluteal muscles. In fractures at the junction of the upper and middle thirds of the thigh, long-axis traction has some reducing force; but in the subtrochanteric area it exerts little or none.

In support of the above statements the following clinical observations may be quoted: In the 51 cases of fracture in the lower third of the femur in our series, we have observed flexion of the lower fragment in 47; in the remaining 4 the fragments were impacted. The flexion has never been completely corrected by long-axis traction in a straight Thomas knee splint. If the finger be passed into the wound on to the top of the lower fragment when the leg is under forced extension in the extended position no reduction of the flexion can be felt to take place beyond a limited point, however great the weight applied; the flexion is felt to be greater when the foot is held at a right angle than when it is allowed to drop, and the flexion of the fragment can be at once increased by powerful dorsiflexion of the foot.

TECHNIQUE OF REDUCTION.

Lower Third of the Femur.—If the case is a clean one, alinement may be obtained at once, and the limb put, after extension, in a bent splint as described below. In general, however, we treat infected cases for two

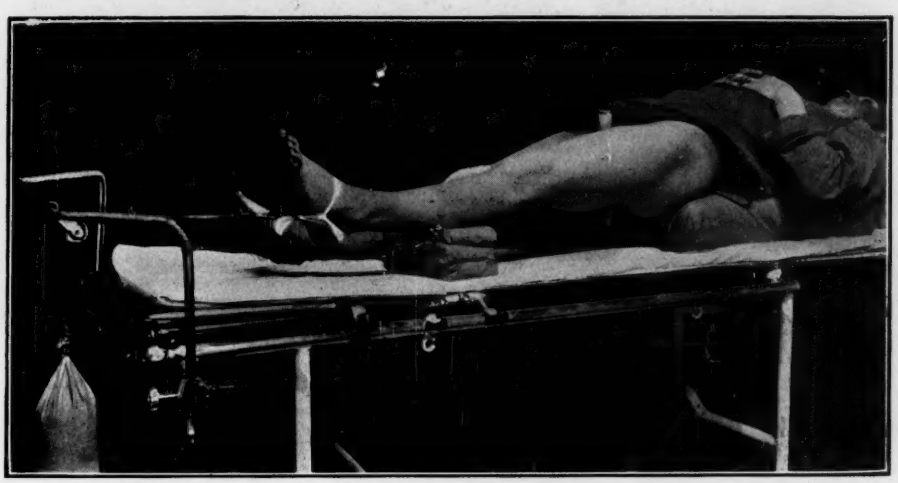


FIG. 32.—Arrangement for exerting weight extension during operation or application of plaster appliances.

or three weeks on a straight Thomas splint. During this period the wound infection will have settled, and by keeping the strap acting on the extension stirrup tight, the limb will have been pulled out to full length. At this stage *x*-ray plates in two planes will show what has to be done. A prophylactic dose of antitetanic serum is given two days before manipulation.

In a few cases anæsthesia may be unnecessary, the fragments practically 'hinging' into position on flexion of the leg at hip and knee. As a rule it will be necessary to put a finger on the wound, to determine the position of the fragments and to guide them into place. Over-extension with a weight (up to 90 lb.), by means of the appliance shown in *Fig.* 32, is effected when free disentanglement of the fragments is required. Sometimes the removal of the tips of the fragments with bone pliers may enable otherwise obstinate

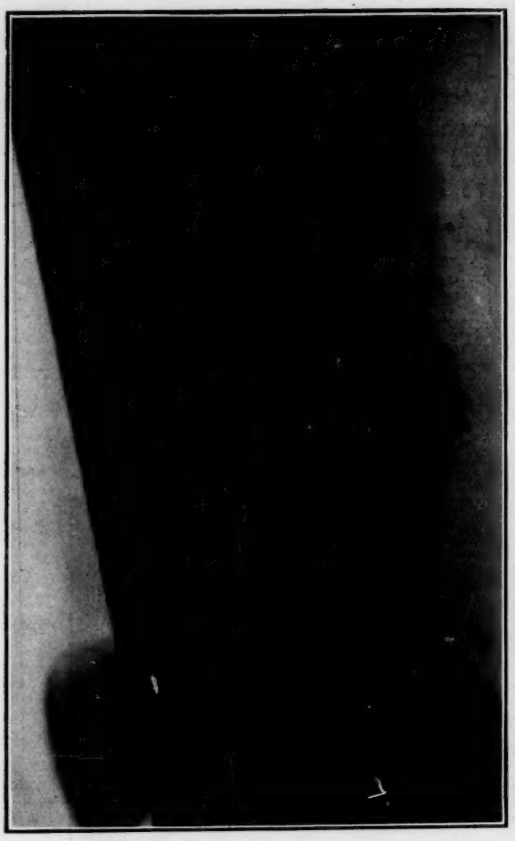


FIG. 33.—Fracture in lower third of the thigh, showing flexion of the lower fragment uncorrected by long-axis extension in a Thomas splint.

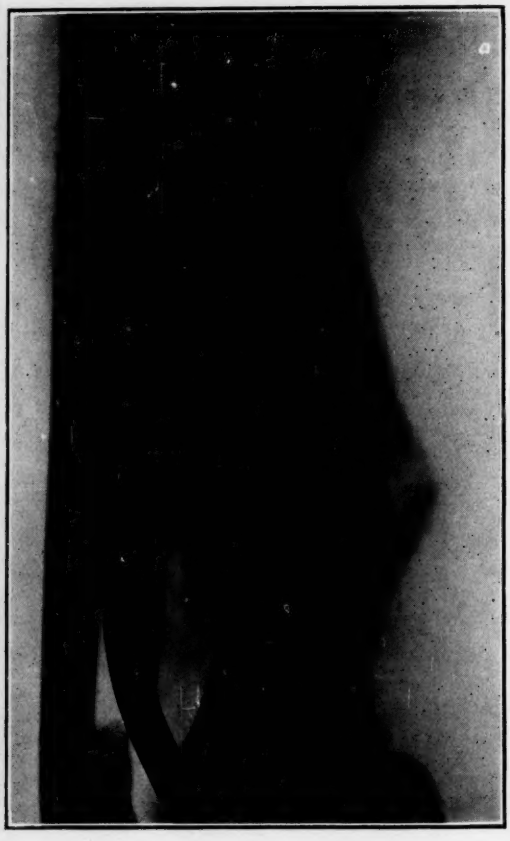


FIG. 34.—The same case after manipulation and fixation in a Thomas splint bent at the knee.

cases to fall into line. At the completion of the manipulation, the fragments should be in one of three positions, viz. : (1) Impacted (*Figs.* 33, 34); (2) Loosely opposed end to end (*Figs.* 35, 36, and 37, 38); (3) Opposed side to side parallel (*Figs.* 39, 40). The last condition must be admitted a failure, and should only occur when the reduction is undertaken too late.

The manipulation having been completed, the limb is kept flexed and extended by an assistant while a Thomas knee splint, bent at an angle of about 45° at or just above the knee level, is applied. The position of the

slings about the fracture requires attention. Two narrow 'fixation' slings of folded linen are applied so as to support the fragments near their ends; that opposing the flexion of the lower fragment is the most important. These two slings should remain constantly in position until consolidation of the fracture has commenced. A 'dressing' sling which controls the wound is applied between the two fixation slings. Extension is applied by a strap as described above, or by means of a weight if more convenient.

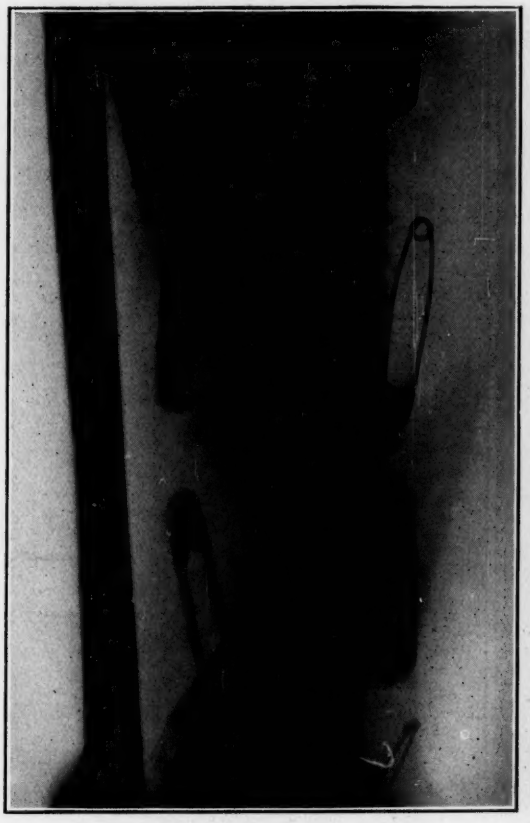


FIG. 35.—Fracture in lower third of the thigh; flexion of the lower fragment not reduced by being pulled out over-length in a Thomas splint.

FIG. 36.—The same fracture put up in the flexed position, after the removal of a bone fragment.

We have not observed any reaction after quiet reposition. When the procedures have been more vigorous, the local infective process may have flared up, but it has never been necessary to alter the position. Œdema of the foot and leg often results from sling pressure in the popliteal space; a little adjustment of sling or extension will remedy this. Sling pressure on the external popliteal nerve is dealt with below.

When the leg is in the flexed position, care must be taken that lateral angulation of the fragments does not occur. Adduction of the upper fragment

is the rule in these cases, and accounts for the tendency of the limb to fall into the position of knock-knee. The adduction results from the action of the adductor muscles, and is accentuated by the position of relative abduction assumed by the injured limb. This abduction is secondary to the tilting down of the pelvis on that side, which occurs in practically every case. If the adduction of the upper fragment is not corrected by long-axis traction, the fragment should be drawn outwards by a small padded splint applied

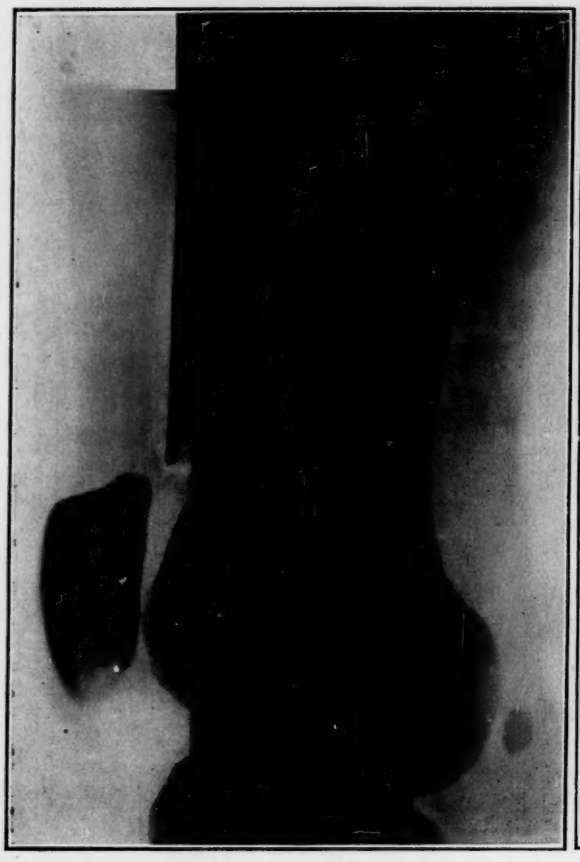


FIG. 37. — Oblique fracture ('concussion' type) in lower third of thigh showing persistent flexion of the lower fragment.

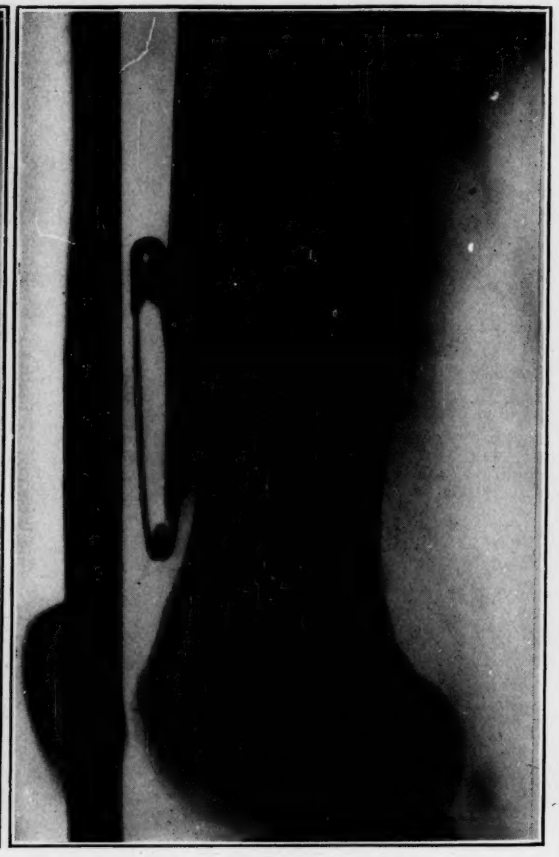


FIG. 38.—The same fracture put up in the flexed position, showing fair reduction of the displacement.

to the inner side of the thigh and strapped across to the outer bar of the splint; the lower fragment may be counterfixed below. This displacement is easily treated in the first few weeks of the injury, but is very difficult to control later.

The treatment of the case is continued in the bent splint till the union is firm. If any degree of impaction has been effected after manipulation, very little extension is required to maintain the position.

Middle and Upper Thirds of the Femur.—The displacement in this class

of injury can be conveniently controlled in the classical Thomas splint. Long-axis traction alone suffices to reduce the fragments. Fractures at the junction of the upper and middle third also often come into line in the same way. If, however, flexion of the upper fragment is not overcome, the methods adopted for subtrochanteric fractures will apply.

Subtrochanteric Fractures.—The upper fragment is in most cases abducted and flexed. The displacement in both directions may be extreme. When the lesser trochanter is detached from the main fragment, the displacement

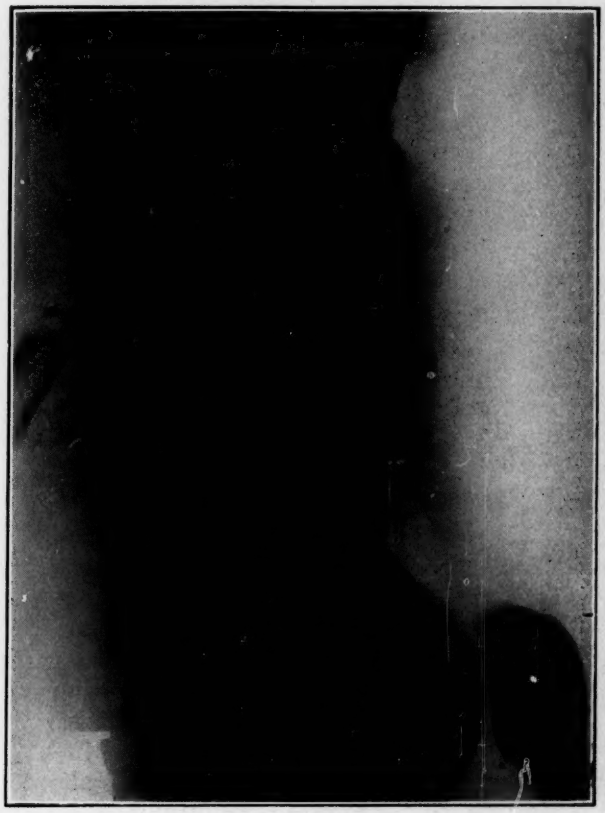


FIG. 39.—Fracture in lower third of the femur, incompletely pulled out on account of the nature of the wounds; marked flexion of lower fragment.

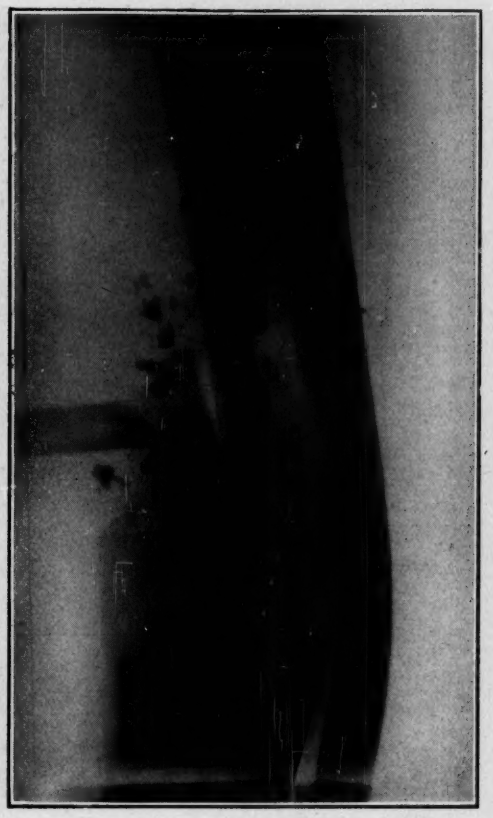


FIG. 40.—The same fracture put up in flexion four weeks after the injury. Correct replacement has not been obtained, but the fragments now lie parallel.

does not occur; and in one instance (*Case* 118), though the lesser trochanter was intact, the lower fragment lay in front of the upper. The lower fragment is usually adducted, or appears to be relatively so.

The upper fragment is quite uncontrollable, and so the aim must be to aline the lower with it as far as possible. A Hodgen splint, employed as described above, is effective in many cases; the important points are to flex the thigh as far as possible, and to arrange a sling to bring the upper end of the lower fragment well forward.

Transfixion of the lower fragment just above the condyles can be of great value in these cases. With fractures at this level, the procedure involves the minimum risk of infection, and renders possible the complete control of the lower fragment. In *Case* 115, adopting this procedure, the thigh was held at a right angle to the body in order to aline the fragments (*Fig.* 27). The limb was maintained in this position for five weeks, and then gradually allowed to drop to the normal.

COMPLICATIONS.

Nerve Injury.—Eleven cases of primary nerve injury were observed in this series. The great sciatic was involved in 6, the external popliteal in 4, and the anterior crural in 1.

Secondary paralysis or paresis in the distribution of the external popliteal occurred in 7 cases, in all but one of which it cleared up within six weeks. The lesion appeared to be due to sling pressure on the nerve in all these cases. The level at which the pressure is most often exerted is near the head of the fibula, but in two cases it seemed probable that the effect was produced in the supracondylar area. This complication should be avoided by leaving the areas mentioned free from pressure as far as possible, or at any rate by relieving it as soon as subjective signs are complained of in the distribution of the nerve in question.

In *Case* 112 complete paralysis of the sciatic nerve developed in the sixth week. The case was one of fracture at the junction of the upper and middle thirds of the bone; the paralysis was possibly due to sling pressure on the nerve over the prominent upper end of the lower fragment.

Treatment during the period under review is limited to control of the foot and the maintenance of the nutrition of the affected muscles by massage. The method used for balancing the foot is detailed above, and illustrated in *Fig.* 25.

Injury to Arteries.—*Primary damage to the main vessel* was noted in 3 cases of the series. In 2 cases the injury was due to rifle-bullet wounds which did not become infected. In *Case* 10 a diffuse aneurysm formed in the lower part of the thigh; the pulsation in this gradually decreased, till at the end of four weeks it was localized to an area the size of a halfpenny. In *Case* 68 an arterio-venous aneurysm formed in the lower end of the common femoral; the size of the swelling diminished during the month the patient was under observation; but ligature of the artery was found to be necessary later, and was carried out in England. In *Case* 59 a shell fragment entered the front of the thigh in the middle line one inch above the upper border of the patella; the missile perforated the femur just above the condyles, and after notching the popliteal artery, lodged under the skin. A progressive painful hæmatoma formed, threatening the nutrition of the leg. Five days after injury the missile was removed, the clot turned out, and the popliteal artery and vein were tied on either side of the injury. The patient made an uninterrupted recovery, without damage to the foot or infection of the knee-joint.

Exposure of the main vessels in the primary wound was noticed in 18 cases; in 5 of these hæmorrhage occurred later.

Secondary hæmorrhage occurred in 17 cases, with 2 deaths. The average time after injury when it occurred was nineteen days, the shortest period being eight, and the longest fifty-one; in the latter case bleeding was definitely due to a sharp fragment perforating the popliteal artery after the changing of a splint. In 6 the bleeding was from the main vessel. The treatment adopted for these cases was amputation in *Cases* 20 and 26, followed by recovery. In the remaining four (*Cases* 33, 39, 111, and 112), the vessel was tied in the wound; the first two died shortly after operation, the others recovered. The bleeding was apparently from minor vessels in 11 cases. Hæmostasis was effected by ligature of the vessel in 2 cases and dry packing in 9. Recurrence occurred in two of the latter cases, and was finally controlled by clamping the bleeding area with artery forceps, which were left *in situ* for three days.

Standard Treatment.—A tourniquet is applied in the first instance; this should not be left on for more than half an hour. As soon as possible afterwards, the patient is anæsthetized and search made for the bleeding point. A good view of the whole wound must be obtained, and any part where fragments may impinge on the main vessels should be especially inspected. If the bleeding vessel can be found, it is ligatured as near as possible to the aperture; if it is necessary to tie the popliteal artery, the vein should also be included. If no vessel is found, a dry gauze pack of the whole wound track is the only resource. The pack should be removed as soon as suppuration has rendered it easily movable—its longer retention will only encourage recurrence of bleeding. Recurrent hæmorrhage appears to be commonly due to failure to locate a fair-sized opening in a vessel at the first inspection.

Osteitis.—In all infected cases some involvement of the bone must be present, but the frequency with which signs of osteomyelitis rapidly pass off is remarkable. In this series, 30 cases of persistent pyrexia were attributed to bone infection; the other less common cause of the condition being a slow-spreading cellulitis with intermuscular abscess formation.

In most cases *x*-ray examination showed definite rarifying osteitis in the region of the fracture, with irregular sequestration. In *Cases* 16 and 46 the fracture was oblique, and the fractured surfaces were separated to the extent of nearly half an inch. A long cavity was thus formed lined with granulating tissue. An operation, entailing full opening of this cavity and packing it with gauze, led to a prompt subsidence of the pyrexia, and to progressive healing, with no apparent probability of sequestrum formation.

Sequestrum Formation.—In the majority of septic cases there is some necrosis of the tips of the main fragments of the bone, as well as of detached pieces. *X* rays (especially stereoscopic views) exhibited the presence and position of dead bone very clearly at a period from six weeks to two months after the injury.

In this series we have removed sequestra from 23 cases at an average period of about two months from the primary injury. It is true that

secondary operations for the same purpose may be necessary, but by no means in all cases. The operation is more easily carried out at this time, before a massive involucrum has formed, and limits the amount of reactive inflammation. Seven weeks was the earliest date after injury at which complete separation of sequestra from the main fragments was noted.

Technique of Operation.—A prophylactic dose of antitetanic serum should always be given. The dead fragments are localized as accurately as possible by means of *x* rays and the probe. The structures are then cleanly divided down to the bone, and the sequestra removed with forceps. No aimless curetting is performed, as this is liable to light up the infective process and to further bone necrosis. The cavity left after removal of the bone fragments is packed with dry gauze for a few days.

Some pyrexia and local œdema were observed in 6 cases after operation, and in 4 cases a sharp attack of erysipelas occurred. Prophylactic vaccination against streptococcal infection had not been employed in any of these cases.

Tetanus.—There were five cases in this series. In two (*Cases* 9 and 97) the symptoms appeared on the sixteenth and fourteenth days respectively, and remained localized to the thigh muscles. Both recovered. In the other three (*Cases* 32, 94, and 110), the symptoms were general from the commencement, and the results fatal. Symptoms commenced forty-four, forty-five, and fifty-four days after injury respectively. In the last-mentioned case some local spasm, which soon passed off, was noticed six days after primary injury; in the second general attack all signs of tetanus had subsided eight days before death, which was due to streptococcal septicæmia, the organism being recovered from the blood. These three cases all received antitetanic serum shortly after they were wounded, but no further injections before the onset of symptoms. It is now customary to give a prophylactic dose of serum every fourteen days while the wounds continue to discharge, and in all cases before any operation or manipulation is undertaken.

Amputations.—In four cases of this series amputation was done. In two (*Cases* 20 and 26) it was performed for secondary hæmorrhage from the main vessel: both recovered. In *Case* 27 the femur was broken at two levels and the knee-joint became infected: recovery took place. In the last (*Case* 24), amputation was performed on the thirteenth day for spreading gas gangrene, with a fatal result.

Massage and Movement.—This cannot be carried out in a thorough way during the period under consideration. The desirability of leaving the foot free has been mentioned above. Movement at the knee-joint can only be practised in cases in which the lower fragment has been transfixed for extension purposes. The whole limb should be massaged as far as the splintage permits in all cases, once they run an afebrile course.

Union.—We have not been able to observe completed union in many cases of this series, but the general table at the end defines the condition, as far as possible, on transfer. Most rapid consolidation was observed in those cases in which there was much local comminution and no infection. Several cases in which there was considerable loss of substance showed remarkable

bone formation within two or three months. *Case* 8 is a good example of this (*Figs.* 41 and 42). The most evident cause militating against bone union is severe infection; mild local continued infection does not appear to hinder the process to any great degree, though it sometimes leads to an excessive inflammatory deposit of weak osseous material.

Ambulatory Treatment.—Whenever the condition and position of the wounds allow, the provision of some apparatus which permits the patient to get about is of inestimable value. The morale of the man rapidly improves, and the wound healing and bone union progress correspondingly.

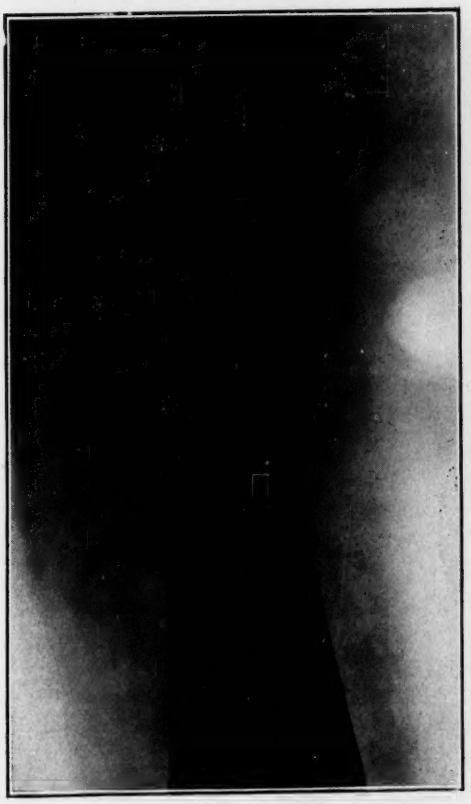


FIG. 41.—Fracture in the middle of the femur one month after injury. Good position. The length was normal. Absence of half to one inch of compact bone is shown.

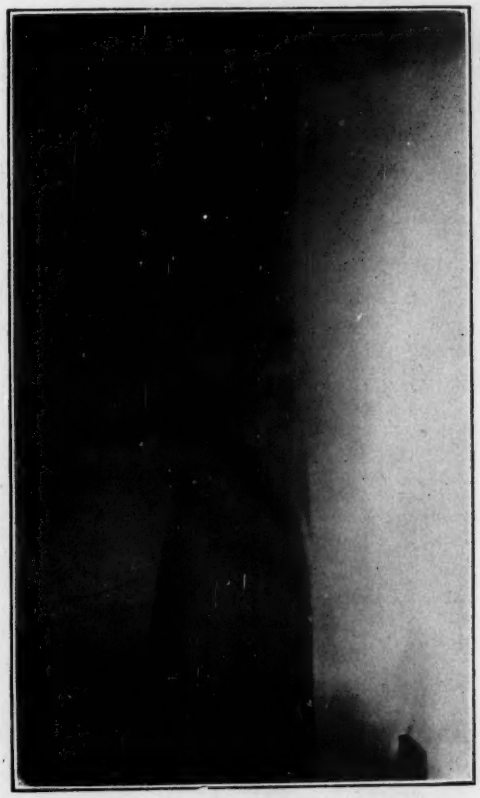


FIG. 42.—The same fracture three months after injury. Considerable new bone formation has taken place.

We have employed an ambulatory appliance[6] in 13 cases of this series. It was applied on an average about two months after the primary injury. In simple cases the apparatus can be used at a much earlier stage, but for infected gunshot cases there should be no pyrexia, and sound commencing union should be present before it is applied.

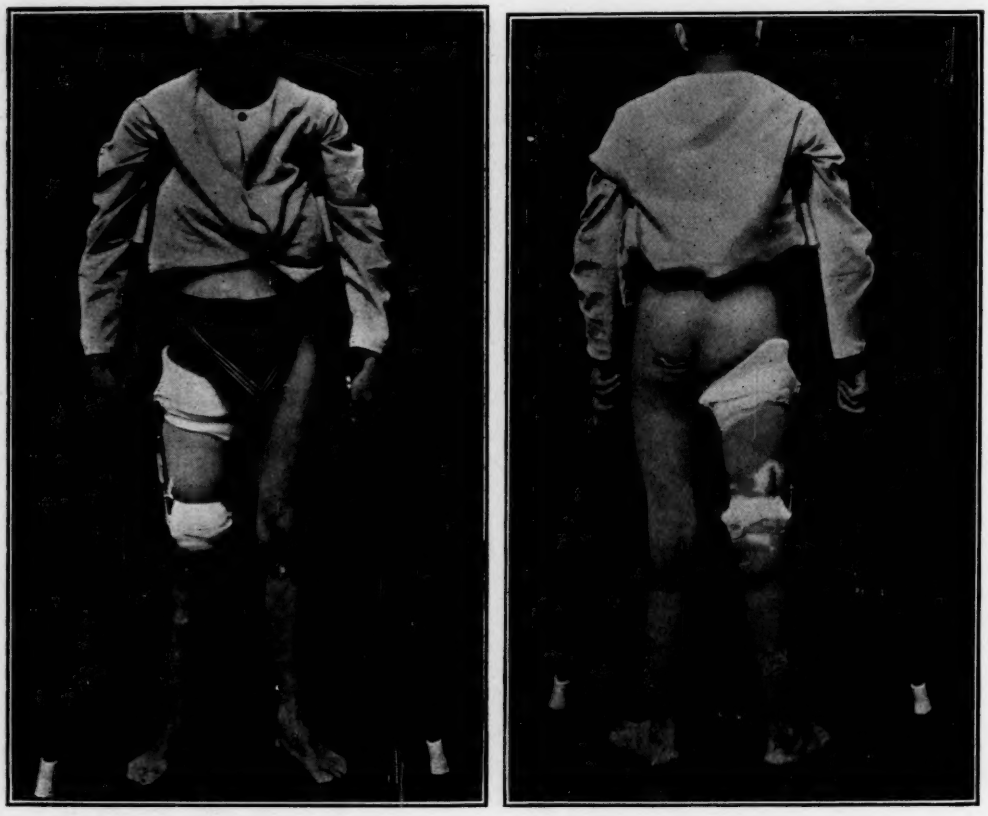
The form of the ambulatory apparatus is shown in *Figs.* 43 and 44; the technique of its application is dealt with elsewhere.[6] It consists of two

moulded plaster-of-Paris collars which are united by two extension screws, on the principle of Hackenbruck's Distraktions-Klammer.[5] The apparatus leaves the knee-joint free, and is easily applied by the surgeon.

SUMMARY.

1. The Thomas knee splint is the most suitable apparatus available for use in the transport of cases of fracture of the femur.

2. The same splint can give excellent results as regards alinement and length in fractures in the middle third of the femur.



FIGS. 43, 44.—Front and back views of ambulatory appliance. The ischial saddle and supracondylar collar are made with plaster of Paris. The two extension screws are set in perforated zinc arches.
In the case illustrated the apparatus was applied two months after injury.

3. Good alinement cannot be attained by the use of the Thomas splint in the case of fractures occurring in the lower third of the femur; but if the splint be modified by bending it at the knee-joint level to form a skeleton double inclined plane, the results are good.

4. Fractures in the upper third of the femur can generally be well treated in a Hodgen splint.

5. Adhesive extension attachments are satisfactory for most cases, and are well suited to the conditions of active service.

6. Transfixion of the bone is useful in special cases, and when the procedure is carried out at a distance from an infective focus.

7. This series of cases demonstrates the importance of periodical prophylactic injections of antitetanic serum.

In conclusion, we wish to acknowledge our indebtedness to Captain J. N. Ferguson, R.A.M.C., for the patience and skill he has expended in taking a large number of *x*-ray photographs and in the preparation of the figures published with this paper.

FATAL CASES.

The following table gives the cause of death, which took place in 10 cases of the series of 125.

Case No.	Cause of Death	Injury	Days between Injury and Death
24	Gas gangrene	Fracture in lower third, injury of knee-joint, amputation	14
29	Septicæmia	Comminution of whole upper third of femur	10
32	Tetanus	Fracture at junction of lower and middle third	45
38	Secondary hæmorrhage from external circumflex at its origin	Subtrochanteric fracture	11
39	Secondary hæmorrhage from profunda femoris	Comminution of whole of upper third of femur; diarrhœa	11
43	Gas gangrene	Fracture of both femurs	4
42	Gas gangrene	Fracture in upper third of femur	6
66	Peritonitis and pelvic cellulitis	Fracture of neck of femur; gunshot wound of bladder	12
94	Tetanus	Fracture in middle third of femur	53
110	Septicæmia (streptococcal) following tetanus	Fracture at junction of middle and lower third of femur	78

[*See table on next page.*

TABLE OF 125 CASES OF GUN-

This Table has been abstracted from the original notes, now filed with the National Research Committee. between receipt of wound and commencement of observation was 78·8 hours. Under the heading "Splint *Hodgen's splint* = Standard Hodgen wire splint; *Thomas's splint* = Thomas knee splint,

No.	Days under Observation	Position of Fracture	Comminution	Degree of Infection	Splint Treatment
1	28	Lower third	6 in., coarse, much loss of bone	Severe	Long outside for transport. Thomas's splint
2	25	In upper third	5 in., coarse, not much loss	Medium	Aluminium splint
3	208	Upper and middle third	3 in., coarse	Medium	As above
4	34	Middle	Slight, oblique fracture	Medium	Thomas's splint
5	39	Lower and middle third	3 in., coarse, much bone removed	Severe	Aluminium splint bent at knee
6	51	Middle	Slight, oblique fracture	Medium	Thomas's splint
7	187	Lower and middle third	Slight, oblique fracture	Medium	Aluminium splint bent at knee
8	51	Middle	6 in., coarse	Clean	Thomas's splint, and ambulatory splint 30th day
9	46	Upper third	Slight, oblique fracture	Severe, local tetanus	Hodgen's splint
10	28	Lower and middle third	3 in., coarse	Clean	Thomas's splint
11	181	Upper and middle third (just below)	3 in., medium	Severe	Wallace's splint
12	52	Middle and lower third (just above)	4 in., great, medium	Severe	Thomas's splint
13	48	Upper and middle third	2 in., coarse	Severe	Aluminium splint
14	37	Middle	2 in., coarse, little displacement	Medium	Thomas's and ambulatory splints
15	53	Lower and middle third (below)	2 in., medium	Severe	Bent Thomas's splint
16	50	Middle	Slight, oblique fracture	Medium	Thomas's splint
17	90	Sub-trochanteric	2 in., coarse	Severe	Hodgen's splint
18	21	Lower and middle third	Very slight, 'flûte en bec'	Medium	Thomas's splint
19	5	Lower and middle third	Local, slight	Medium	Thomas's splint
20	40	Lower and middle third	Moderate	Severe	Thomas's splint. Amputation

SHOT FRACTURE OF THE THIGH.

The order in which the cases have been entered is not strictly chronological. The average period elapsing
Treatment," the splint mentioned is that which was finally used in obtaining and maintaining alinement.
standard pattern; *Aluminium splint* = Modified Thomas type referred to in the text.

Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
—	Recovery	1 in.	Good	Slight	—
External popliteal nerve paralysis	Recovery	1¼ in.	Good	Slight	—
Transient foot drop	Recovery	¾ in.	Fair	Firm	Ambulatory treatment
—	Recovery	½ in.	Good	Slight	'Concussion' fracture
—	Recovery	1¼ in.	Fair	None	Femoral artery exposed in wound; much bone lost
—	Recovery	¾ in.	Good	Fairly firm	'Concussion' fracture
Persistent pyrexia from osteitis and intermuscular abscess formation	Recovery	½ in.	Good	Firm	—
—	Recovery	¾ in.	Good	Firm	—
Persistent pyrexia from osteitis; local tetanus	Recovery	½ in.	Fair	Firm	Local tetanic symptoms lasted 24 days
Arterio-venous aneurysm of common femoral	Recovery	½ in.	Good	Slight	Aneurysm decreased in size while under observation
Persistent temperature and œdema secondary to osteitis	Recovery	1½ in.	Fair	Firm	Tense and persistent effusion into knee-joint
Persistent pyrexia due to osteitis	Recovery	1½ in.	Fair	Slight	Considerable loss of bone
—	Recovery	½ in.	Good	Slight	—
—	Recovery	½ in.	Good	Slight	—
Secondary foot drop	Recovery	¼ in.	Good	Slight	Large explosive wound, femoral artery exposed
Pyrexia from infected bone cavity	Recovery	¾ in.	Good	Fairly firm	—
External popliteal paralysis	Recovery	1 in.	Poor	Firm	Large explosive exit wound
Complete external popliteal paralysis	Recovery	¾ in.	Fair	Slight	'Concussion' fracture'
—	Recovery	½ in.	Good	None	—
Secondary hæmorrhage from femoral artery 22nd day	Amputation; recovery	—	—	—	Amputation for secondary hæmorrhage

Continued on next page.

TABLE OF 125 CASES OF GUNSHOT FRA

No.	Days under Observation	Position of Fracture.	Comminution	Degree of Infection	Splint Treatment
21	120 (walking)	Upper and middle third	2 in., medium	Severe	Aluminium and ambulatory splints
22	101 (walking)	Upper third	3 in., medium	Severe	Thomas's and ambulatory splints
23	113 (walking)	Middle	2 in., slight; considerable loss of bone	Mild	Thomas's and ambulatory splints
24	9	Lower and middle third	3 in. extreme	Severe, gas	Aluminium splint
25	15	Upper and middle third	Slight, spiral fracture	Clean	Thomas's splint
26	45	Supracondylar	2 in., extensive and fine, into joint	Severe	Aluminium splint
27	62	Upper and lower third (2 fractures)	Slight at both levels	Severe	Right, Thomas's splint; left aluminium splint
28	45	Junction of upper and middle third	2 in., medium, considerable loss of bone	Severe	Aluminium splint
29	3	Trochanter and below	4 in., medium, extensive	Severe	Thomas's splint
30	64	Middle	2 in., slight, coarse	Severe	Thomas's splint; ambulatory splint on 50th day
31	23	Upper third and middle	2 in., coarse, moderate	Severe, anaerobic	Aluminium splint
32	42	Lower and middle third	2 in., marked, medium	Severe	Thomas's bent splint
33	6	Sub-trochanteric	Slight	Severe	Thomas's splint
34	34	Lower and middle third	2 in., coarse, medium	Moderate	Thomas's splint
35	18	Just below middle	Slight	Moderate	Thomas's splint
36	63	Upper and middle third	3 in., coarse, much	Severe	Thomas's splint
37	20	Above middle	Slight	Moderate	Thomas's splint
38	10	Middle	3 in., slight, coarse	Slight	Thomas's splint
39	7	Trochanter, great	Much, fine	Severe	Thomas's splint
40	8	Middle and lower third	Slight, coarse	Clean	Thomas's splint
41	50	Sub-trochanteric	1½ in., coarse, fine, medium	Severe	Aluminium splint

FRACTURE OF THE THIGH—*continued.*

Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
—	Recovery	1 in.	Fair	Fairly firm	One sequestrectomy; wound completely healed on transfer
—	Recovery	¾ in.	Good	Firm	Two sequestrectomies: wound nearly healed on transfer
Paralysis in sciatic distribution, passed off in 7th week	Recovery	½ in.	Perfect	Firm	One sequestrectomy, wound healed on transfer
Spreading gas infection; amputation 13th day	Amputation; death	—	—	—	Death from toxæmia 14th day
—	Recovery	½ in.	Good	None	'Concussion' fracture
Popliteal artery exposed; secondary hæmorrhage 25th day; infection of knee-joint	Amputation; recovery	—	—	—	Amputation for secondary hæmorrhage; knee-joint infected
Infection of right knee-joint (streptococcal)	Amputation above right knee 55th day	—	—	—	Amputation for infection
Pyrexia persistent	Recovery	1 in.	Good	Slight	Explosive type exit wound
General toxæmia from gas and streptococcal infection	Death	—	—	—	Death on 6th day
Complete persistent external popliteal paralysis	Recovery	1 in.	Good	Fairly firm	—
Profunda femoris exposed in wound	Recovery	½ in.	Good	Slight	German
Tetanus on 44th day	Death	¾ in.	—	—	Died in a spasm 15 hours after onset of tetanic symptoms
Secondary hæmorrhage from external circumflex near origin, 9th day	Death	—	—	—	Died 10 hours after operation for bleeding; anæmia and toxæmia
—	Recovery	None	Perfect	Slight	—
—	Recovery	None	Good	Slight	—
Secondary hæmorrhage from external circumflex, 31st day	Recovery	½ in.	Fair	Fairly firm	Vessel tied in wound
—	Recovery	None	Perfect	Slight	—
—	Recovery	None	Perfect	Slight	—
Hæmatoma about profunda femoris; secondary hæmorrhage 11th day; diarrhœa, general toxæmia	Death	—	—	—	Death 5 hours after ligature of vessel
—	Recovery	None	Good	None	—
—	Recovery	1½ in.	Fair	Slight	—

Continued on next page.

TABLE OF 125 CASES OF GUNSHOT FRA

No.	Days under Observation	Position of Fracture.	Comminution	Degree of Infection	Splint Treatment	
42	1	Right, middle; left, lower and middle third	Right and left, moderate	Severe, local gas	Right Liston splint; left, Thomas's splint	Gas to
43	2	Sub-trochanteric	Moderate	Severe, gas gangrene later	Thomas's large ring splint	Gas
44	93	Middle and lower third	2 in., much, coarse	Severe	Thomas's bent splint	Per my
45	15	Sub-trochanteric	Slight	Clean	Thomas's large ring splint	
46	64	Middle	Slight	Severe	Thomas's splint	Per
47	26	Lower and middle third	4 in., gross, extensive	Clean	Thomas's splint	
48	11	Middle	Slight	Clean	Thomas's splint	
49	37	Middle	Slight	Severe	Thomas's splint	
50	33	Upper and middle third	Slight, local	Severe	Thomas's splint	Fem
51	28	Above middle	Slight, local	Clean	Thomas's splint	
52	22	Sub-trochanteric	2 in., coarse	Severe	Thomas's splint	
53	68	Sub-trochanteric	Slight	Severe	Hodgen's splint	Tra
54	9	Middle	Moderate	Mild	Thomas's splint	
56	64	Lower third	Slight	Severe	Thomas's bent splint	Fem
57	50	Lower third	4 in., coarse and fine; much bone lost	Severe	Thomas's bent splint	Per os
58	64	Sub-trochanteric	Moderate	Severe	Hodgen's splint	Per
59	8	Supracondylar perforation	Perforation, with slight fragmentation	Clean	Thomas's splint	Pop
60	71	Middle and lower third	1 in., fine, and some large	Severe	Thomas's splint	Per
61	58	Lower third	3 in., severe, some large	Severe	Thomas's bent splint	Per m
62	62	Sub-trochanteric, much of shaft below	4 in., very marked, fine and large	Severe	Thomas's splint	
63	58	Below middle	5 in., coarse	Severe	Thomas's splint	Fem
64	41	Below middle	3 in., moderate, much lost	Moderate	Thomas's splint	Fem
65	21	Lower third, oblique fracture	Very little, fine	Mild	Thomas's splint	
66	8	Upper third, sub-trochanteric	2 in., moderate	Severe	Hodgen's splint	Wo in

NSHOT FRACTURE OF THE THIGH—*continued.*

	Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
; left,	Gas gangrene, right leg; general toxæmia	Death	—	—	—	Died 1 day after admission
plint	Gas gangrene; general toxæmia	Death	—	—	—	Died 2 days after admission
	Persistent temperature; osteomyelitis	Recovery	½ in.	Fair	Firm	Temperature settled after sequestrectomy
plint	—	Recovery	—	Good	None	—
	Persistent temperature; osteitis	Recovery	½ in.	Good	Fairly firm	Temperature settled after sequestrectomy
	—	Recovery	None	Good	Slight	—
	—	Recovery	½ in.	Good	None	—
	—	Recovery	½ in.	Fair	Slight	—
	Femoral artery exposed in wound	Recovery	½ in.	Good	Slight	—
	—	Recovery	None	Perfect	Slight	—
	—	Recovery	½ in.	Fair	Slight	—
	Transient foot-drop	Recovery	½ in.	Good	Fair	Foot-drop secondary to sling pressure
	—	Recovery	None	Perfect	None	—
	Femoral artery exposed in wound	Recovery	½ in.	Good	Firm	Large explosive exit wound
	Persistent temperature due to osteitis	Recovery	1 in., much bone lost	Good	Slight	—
	Persistent pyrexia	Recovery	½ in.	Good	Fairly firm	Pyrexia probably due to bone infection; sequestrectomy
	Popliteal artery cut laterally	Recovery	—	Perfect	Incomplete fracture	Popliteal artery and vein tied on 5th day; uncomplicated
	Persistent pyrexia from osteitis	Recovery	1 in.	Fair	Firm	Temperature settled after sequestrectomy
	Persistent pyrexia due to osteomyelitis	Recovery	½ in.	Good	Fair	As above
	—	Recovery	½ in.	Fair	Fairly firm	—
	Femoral artery exposed in wound	Recovery	1 in.	Good	Slight	Considerable loss of bone
	Femoral artery exposed in wound	Recovery	½ in.	Good	None	—
	—	Recovery	None	Fair	Slight	—
	Wound of bladder; urinary fistula in thigh	Death	—	—	—	Death due to toxæmia secondary to peritonitis and pelvic cellulitis

Continued on next page.

TABLE OF 125 CASES OF GUNSHOT

No.	Days under Observation	Position of Fracture	Comminution	Degree of Infection	Splint Treatment
67	29	Lower third	Moderate, local	Mild	Aluminium splint
68	32	Sub-trochanteric	3 in., moderate	Moderate	Thomas's splint
69	38	Upper third	Slight, local	Moderate	Thomas's splint
70	58	Lower and middle third	3 in., coarse	Severe	Aluminium bent splint
71	45	Sub-trochanteric	2 in., coarse	Severe	Thomas's bent splint
72	30	Sub-trochanteric	2 in., fine, and some large	Severe	Hodgen's splint
73	82	Upper third	3 in., coarse	Severe	Thomas's splint
74	35	Lower third	Slight, 'flûte en bec'	Mild	Thomas's bent splint
75	36	Supracondylar	Slight, impacted	Severe	Thomas's splint
76	35	Middle	None, 3 in. oblique fracture	Mild	Thomas's splint
77	34	Right, lower third; left, lower third	2 to 3 in., coarse, both sides	Both clean	Aluminium splint
78	74	Sub-trochanteric	Whole upper third, fine and coarse, exceptional	Severe	Hodgen's splint
79	26	Lower third	None, 4 in., oblique	Mild	Thomas's splint
80	36	Supracondylar, an inch above	1½ in., coarse	Mild	Thomas's bent splint
81	50	Middle third	Slight, local	Mild	Hodgen's splint
82	80	Supracondylar	None (impact fractures?)	Severe	Thomas's bent splint
83	73	Sub-trochanteric	3 in, large	Severe	Thomas's large ring splint
84	56	Lower third	Slight, local	Mild	Thomas's bent splint
85	68	Supracondylar	1 in., slight	Mild	Thomas's bent splint
86	64	Lower and middle third	None, oblique fracture	Severe	Thomas's splint
87	48	Sub-trochanteric	4 in., much, large	Moderate	Thomas's splint
88	62	Middle	4 in., much, large	Moderate	Thomas's splint
89	63	Lower third	4 in., much, large	Severe	Thomas's bent splint
90	77	Lower third	4 in., slight, large	Moderate	Thomas's bent splint

FRACTURE OF THE THIGH—*continued*

Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
—	Recovery	None	Good	Slight	—
Arterio-venous aneurysm of common femoral	Recovery	None	Good	Slight	Typical bruit over aneurysm, which diminished in size during period of observation
Femoral artery exposed in missile track	Recovery	½ in.	Good	Fairly firm	—
—	Recovery	½ in.	Good	Slight	—
Amputation of left arm for gas gangrene	Recovery	None	Perfect	Fair	—
Sciatic trunk exposed; partial paralysis in its distribution	Recovery	2 in.	Bad	None	Irreducible flexion and abduction of upper fragment
Gunshot fracture patella and infection of knee on same side	Recovery	2 in.	Good	Firm	Extension impossible on account of knee infection
—	Recovery	½ in.	Perfect	Slight	'Concussion' fracture
Sciatic nerve and popliteal artery exposed, no foot-drop	Recovery	None	Perfect	Slight	Impacted fracture
—	Recovery	½ in.	Good	None	—
—	Recovery	None	Fair on both sides	Fairly firm	—
Foot-drop secondary to sling pressure	Recovery	½ in.	Good	Slight	Foot-drop passed off in five weeks
—	Recovery	½ in.	Perfect	Fair	'Concussion' fracture
—	Recovery	None	Perfect	Fairly firm	Fracture impacted after manipulation
Secondary hæmorrhage from perforating branch of profunda 8th day	Recovery	None	Perfect	Slight	Vessel tied in wound, no recurrence
—	Recovery	½ in.	Good	Fairly firm	'Concussion' fracture
Secondary hæmorrhage from small vessel 15th day	Recovery	½ in.	Fair	Firm	Wound packed for bleeding; no recurrence
—	Recovery	None	Good	Firm	—
—	Recovery	None	Good	Firm	—
Complete paralysis in distribution of external popliteal nerve	Recovery	½ in.	Good	Firm	'Concussion' fracture
—	Recovery	None	Fair	Fairly firm	—
—	Recovery	None	Perfect	Firm	—
Persistent pyrexia due to recurrent abscess formation	Recovery	None	Good	Fairly firm	Three operations for local abscess
—	Recovery	½ in.	Good	Firm	—

Continued on next page.

TABLE OF 125 CASES OF GUNSHOT FR

No.	Days under Observation	Position of Fracture.	Comminution	Degree of Infection	Splint Treatment
91	60	Lower third and middle	2 in., slight, large	Severe	Thomas's splint
92	63	Middle	3 in., coarse, moderate	Severe	Thomas's splint
93	68	Middle	3 in., coarse, slight	Severe	Thomas's splint
94	53	Upper third	4 in., much	Severe, tetanus	Hodgen's splint
95	52	Sub-trochanteric	3 in., coarse	Severe	Hodgen's splint
96	100	Lower third	3 in., much, coarse	Severe	Thomas's bent splint
97	34	Middle	4 in., coarse	Moderate	Thomas's splint
98	51	Upper third	3 in., coarse	Moderate	Hodgen's splint
99	39	Middle	None, oblique fracture	Moderate	Thomas's splint
100	28	Lower third, oblique	None	Moderate	Thomas's splint
101	65	Lower third (practically supracondylar)	3 in., coarse	Severe	Thomas's bent splint
102	60	Lower third to middle	3 in., moderate	Severe	Thomas's splint
103	31	Lower third (practically supracondylar)	2 in., coarse, slight	Moderate	Thomas's bent splint
104	74	Sub-trochanteric	2 in., moderate	Severe	Hodgen's splint
105	60	Upper third and middle	2 in., moderate	Moderate	Thomas's splint
106	84	Middle	4 in., coarse and fine	Moderate	Thomas's bent splint
107	114	Supracondylar	2 in., much, medium	Mild	Thomas's flexed and ambulatory splints
108	68	Sub-trochanteric	3 in., medium	Severe	Hodgen's splint
109	85	Middle	1 in., slight	Severe	Thomas's bent and ambulatory splints
110	77	Lower third, 2 in. above condyles	2 in., moderate	Severe, tetanus	Thomas's bent splint
111	90	Lower third	Slight, local	Severe	Thomas's bent splint

FRACTURE OF THE THIGH—*continued.*

Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
Secondary hæmorrhage from small vessel 12th day	Recovery	None	Good	Fairly firm	Wound packed for bleeding; no recurrence
Femoral artery exposed in wound; persistent pyrexia due to osteitis	Recovery	½ in.	Good	Fairly firm	—
Persistent pyrexia due to intermuscular abscess formation	Recovery	None	Good	Fairly firm	—
Tetanus on 44th day	Death	—	—	—	Death from exhaustion 9 days after onset of tetanus
—	Recovery	None	Good	Fairly firm	—
Persistent pyrexia from subacute cellulitis and intermuscular abscess formation	Recovery	½ in.	Good	Firm	—
Complete division of sciatic nerve; local tetanus 14th to 21st days	Recovery	None	Good	Slight	No recovery in sciatic nerve while under observation
—	Recovery	None	Good	Fairly firm	—
—	Recovery	None	Perfect	Firm	'Concussion' fracture
—	Recovery	None	Good	Fairly firm	—
—	Recovery	None	Good	Slight	—
Persistent pyrexia due to osteitis	Recovery	½ in.	Fair	Fairly firm	—
—	Recovery	½ in.	Good	Slight	—
Persistent pyrexia from osteitis	Recovery	½ in.	Good	Firm	Temperature settled after sequestrectomy
—	Recovery	None	Good	Firm	Transfixion extension
Complete foot-drop (primary), recovered in 4 weeks	Recovery	½ in.	Good	Firm	—
Knee-joint perforated	Recovery	None	Perfect	Firm	Impaction of fragments after manipulation
Secondary hæmorrhage 14th day from external circumflex	Recovery	½ in.	Fair	Fair	Hæmorrhage controlled by clamp after failure of pack: no recurrence
Secondary hæmorrhage 10th day from small vessel	Recovery	None	Perfect	Fairly firm	Bleeding controlled by pack; no recurrence
Sciatic paralysis; tetanus 54th day; streptococcal septicæmia	Death	—	—	—	Death from septicæmia 9 days after tetanic symptoms had subsided
Secondary hæmorrhage from popliteal artery 51st day	Recovery	½ in.	Good	Fairly firm	Popliteal artery and vein tied for bleeding; uncomplicated; no recurrence

Continued on next page

TABLE OF 125 CASES OF GUNSHOT

No.	Days under Observation	Position of Fracture.	Comminution	Degree of Infection	Splint Treatment
112	160	Upper third and middle	Slight, local	Severe	Hodgen's splint
113	100	Middle	3 in., coarse	Severe	Thomas's splint
114	101	Lesser trochanter detached	2 in., coarse	Severe	Hodgen's splint
115	120	Sub-trochanteric	Local	Moderate	Suspension at a right angle
116	89	Sub-trochanteric	3 in., coarse	Severe	Hodgen's splint
117	90	Sub-trochanteric	3 in., moderate	Severe	Hodgen's splint
118	110	Sub-trochanteric	4 in., coarse, much	Severe	Hodgen's splint
119	100	Lower third and middle	2 in., coarse	Moderate	Thomas's bent splint
120	100	Lower third; 'concussion' fracture	Local, slight	Mild	Thomas's bent splint
121	110	Upper third and middle	Local, slight	Severe	Hodgen's splint
122	90	Sub-trochanteric	Local, slight	Severe	Hodgen's splint
123	72	Lower third	Local, slight	Mild	Thomas's bent splint
124	90	Sub-trochanteric	1 in., medium	Severe	Hodgen's splint
125	45	Middle	1 in., fine	Mild	Hodgen's splint

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[1] Lieut.-Col. Robert Jones, "The Mechanical Treatment of Fractures under War Conditions," *Brit. Med. Jour.*, 1916, Dec.
[2] Major E. W. Hey Groves, "The Treatment of Fractures of the Femur," *Brit. Jour. Surg.*, 1916, April, and elsewhere.
[3] Stimson, *A Treatise on Fractures and Dislocations*, 7th ed., 1913, pp. 103 and 394.
[4] Wilms, quoted by Steinmann in *Die Nagelextension der Knochenbrüche*, Stuttgart, 1912.

FRACTURE OF THE THIGH—*continued.*

Complications	Result	Shortening	Alinement	Union on Transfer	Remarks
Recurrent secondary hæmorrhage; secondary persistent sciatic paralysis; erysipelas	Recovery	½ in.	Good	Slight	Hæmorrhage four times—33rd, 42nd, 49th, and 52nd days; profunda femoris tied on last occasion
Secondary hæmorrhage 15th day from small vessel	Recovery	½ in.	Good	Slight	Bleeding controlled by pack; no recurrence
—	Recovery	½ in.	Fair	Firm	—
Complete paralysis in distribution of sciatic nerve	Recovery	None	Good	Fairly firm	Extension by transfixion
—	Recovery	1 in.	Fair	Fairly firm	Much loss of bone
Persistent secondary foot-drop; secondary hæmorrhage 21st day	Recovery	½ in.	—	Fairly firm	Bleeding controlled by pack; no recurrence
—	Recovery	None	Good	Firm	—
Secondary hæmorrhage 14th day from small vessel	Recovery	None	Fair	Firm	Bleeding controlled by pack no recurrence
—	Recovery	None	Good	Firm	—
Secondary hæmorrhage 9th day from small vessel	Recovery	None	Fair	Fairly firm	Bleeding controlled by pack; no recurrence
Empyema secondary to chest wound	Recovery	None	Good	Fairly firm	—
—	Recovery	None	Good	Fairly firm	—
Secondary hæmorrhage from small vessel	Recovery	None	Fair	Slight	Bleeding controlled by pack; no recurrence
Wound of spine; cauda equina lesion; incontinent	Recovery	None	Perfect	Fair	At one period the thigh was overpulled 1 in.; cauda lesion recovering

[5] Hackenbruck, "Zur Ambulanten Behandlung von Knochenbrüchen mittels Distraktions-Klammern," *Münch. med. Woch.*, lix, 1487.

[6] Captain C. Max Page, "An Ambulatory Apparatus for Fractures of the Femur," *Brit. Med. Jour.*, 1917.

[7] Captain C. Max Page, "The Transport of Cases of Fractured Thigh," *Brit. Med. Jour.*, 1915, July.

[8] Major Hey Groves, *On Modern Methods of Treating Fractures*, Bristol, 1916.

SOME SPLINTS FOR THE TREATMENT OF GUNSHOT FRACTURES OF THE LONG BONES.

By J. HOGARTH PRINGLE, Glasgow.

If any one opinion can be formed regarding the treatment of fractures of the long bones caused by gunshot injury during the course of the war, it is that surgeons have found the methods usually employed in civilian practice not satisfactory, and especially would this appear to have been the case in dealing with fractures of the single bones—the humerus and femur. Almost constantly comminuted, with extensive lacerations of the surrounding muscles, a large number of them septic in the highest degree, it is essential that any method of treatment, to be efficient, should afford effective support; and, by whatever means this is provided, there must also be free access to the wound, which requires continual dressing, whether that be by irrigation or by the application of absorbent materials.

SPLINTS FOR THE LOWER EXTREMITY.

For the treatment of fractures of the femur caused by gunshot injury, the Thomas knee splint has been extensively advocated, and, I believe, made use of. I readily admit that this splint is a very excellent appliance in the condition which it was originally designed to treat—namely, chronic disease of the knee-joint, the rather special feature of which is that re-application of the dressing, as well as of the splint itself, is only required at long intervals. As far as my experience enables me to form any opinion on the subject of septic gunshot fractures of the femur, the Thomas knee splint seems unsuited for anything more than the most temporary treatment of these injuries. I think all the cases of this nature that have come under my care have been sent me with a Thomas knee splint applied as the means of fixation of the fracture; I will only say that it has been altogether unsatisfactory, and that my endeavour has always been to get rid of it at the earliest opportunity.

The form of splint I have employed for my cases of septic gunshot fractures of the lower limb is one I have used in treating some of the open septic fractures that are met with in civilian hospital practice, and with which I have to deal so frequently at the Glasgow Royal Infirmary. There I often have to treat cases which it is impossible to make aseptic, but I nevertheless fix them by some means, plating or wiring (as described in my paper, "Analysis of 230 Cases of Open Fracture treated by Operative Methods," *Brit. Jour. of Surg.*, ii, 102), leave the wound or wounds open, and dress them regularly and often; I remove the plate when consolidation of the tissues around is sufficient to hold the fragments of bone in position. *Fig.* 45 shows a window cut in a splint of this kind to allow access to the wound in a

case of open fracture of the femur that was treated on these lines. The patient in question wore this splint for seven weeks consecutively. The dressings were carried out with ease, and without any disturbance of the patient or his fractured bone, and solid union was obtained, with a useful limb.

My first experience of a septic gunshot fracture of the femur occurred in May, 1915, when a man was sent on to the Glasgow Royal Infirmary from France, where his left lower limb had been amputated through the upper third of the thigh, and he had also a highly septic comminuted fracture of the right femur just below the trochanters. The state of this thigh and the general condition of the patient were so bad, that I have no doubt, had the left limb not already been removed, I would have amputated the right one. I applied one of the splints described, modified in that it had a ring attached at its upper end in order to give a steadying effect and also to enable counter-extension to be applied. It acted most satisfactorily: no sagging of the ends of the bone fragments took place at the site of fracture; and the daily dressings, applied through the windows cut in the splint—which, until its

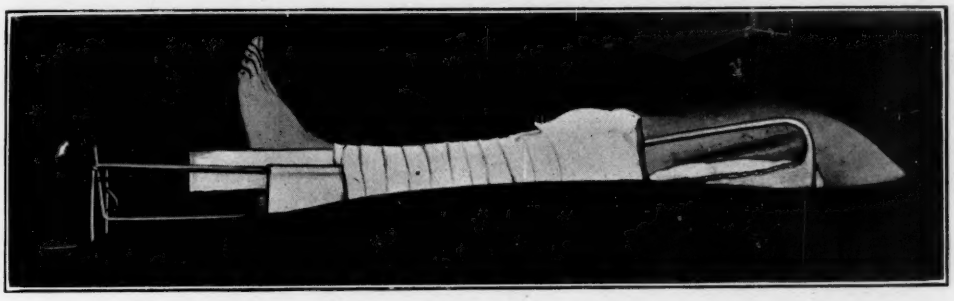


FIG. 45.—Open fracture of the femur which has been plated and the wound left unclosed. The limb is in a wire splint with a window for dressing. Light elastic extension is applied to steady the limb in the splint.

application, had been a most trying ordeal—became at once easy for the patient as well as for the dresser, and firm union of the bone was ultimately obtained.

The splints have done so well in all the cases of gunshot fractures of the limbs which have come under my care, that I hope a description of them may be of use to others who have to deal with similar cases.

I use two types of splint, one for the lower and the other for the upper extremity. The foundation of both is a skeleton of wire, made to measure for the individual patient. The splints for the lower limb are made in the form of a simple long trough. The body of the splint is made by covering the wire skeleton with lint or flannel (the former is cheaper, but a well-covered flannel splint is extremely strong), which is then impregnated with a mixture of resin and paraffin wax. When this mixture sets, as it does quickly, the body is rendered practically as hard as wood; but it can still be cut easily with a warmed knife, to make one or more windows opposite any wounds which require to be dressed. A window may also be fashioned during the making of the skeleton splint (*Fig.* 46 A), and this is a decided advantage if

a large window should be required, particularly at the back of the lower limb, because the strength of the splint is not then interfered with. The resin mixture is not absorbent, and will hold out for weeks on end.

The idea of employing paraffin wax and lint I borrowed from Sir William Macewen, who used for his excisions of the knee-joint a splint made of wire modelled for this special purpose, so that when covered with lint impregnated with ordinary paraffin wax, it constituted two gutters, one for the thigh and one for the leg. I have used this splint for almost every excision of the knee-joint that I have done, and, in my opinion, there is nothing better for the purpose. But it is not suited for the treatment of septic fractures. Lint impregnated with paraffin wax only, while admirably suited for aseptic cases, does not stand up to the constant contact with the warm and copious discharges that come from the thoroughly septic fractures resulting from gunshot

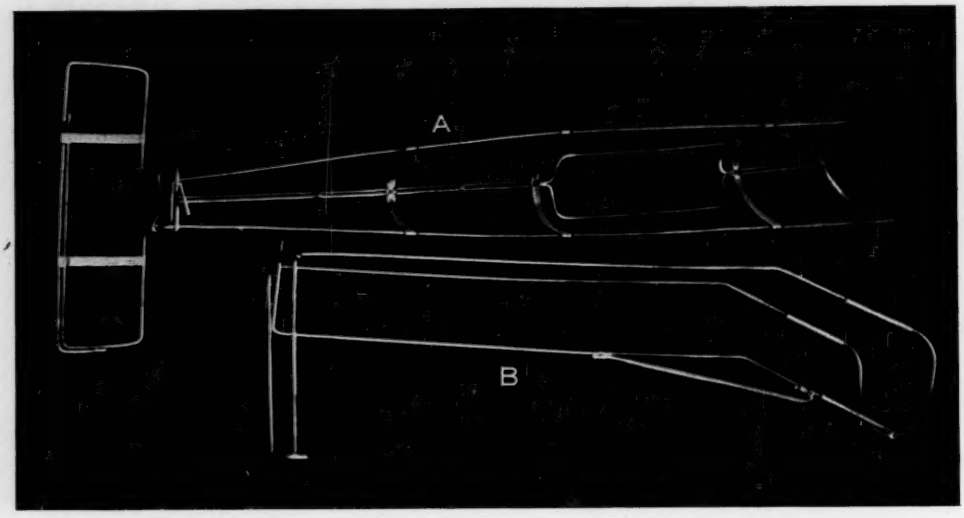


FIG. 46.—A. Skeleton splint with a large window for wound at the back of the limb. B. Telescoping angled splint. The thigh piece can be varied in length 3 inches.

injuries in this war. At present, after many trials to obtain a hard composition for stiffening the lint or flannel, I am using a mixture of resin 3 parts, hard paraffin wax 1 part, and precipitated chalk $\frac{1}{4}$ part, by weight. This mixture is taken up by the lint much better than is paraffin wax alone; it is much harder when it sets; it resists the warmth of the body and of the discharges from the wound much better than does the paraffin; and it is still quite easy to cut windows in it.

Many of the splints have been made by Messrs. Rowat & Co., Ltd., Wire Workers, Watson Street, Glasgow, to whom I am much indebted for their help and courtesy. All the splints, whether for the upper or lower extremity, which they have made for me, have fulfilled the objects I had in view to my complete satisfaction; and in this respect I am very fortunately placed, as I can have splints made to my own measurements and special instructions

regarding any modifications that may be required for a given patient, with comparatively little delay. The splints which Messrs. Rowat & Co. construct for me are made of tinned iron wire (No. 6 B.W.G.), and I have no doubt that for general purposes this material is strong enough for any limb. It is, however, a matter of the first importance that the splint shall fit the patient who is to use it, and it is a great advantage if any special feature in a case of fracture can be met in the process of making the skeleton splint. The tinned iron wire is, however, so rigid that it can only be worked, with reasonable expedition, by a practical worker; and as a substitute that could be worked by an amateur, I tried aluminium wire, and found that this material (No. 2 and No. 3 B.W.G.) could easily be turned up to make a splint that could be readily adapted to any wounds that might be present. Windows, where they are found necessary, can be fashioned during the making of the skeleton, so that the strength of the splint will not be affected. It is particularly at the back of the lower limb that a window may be required, and

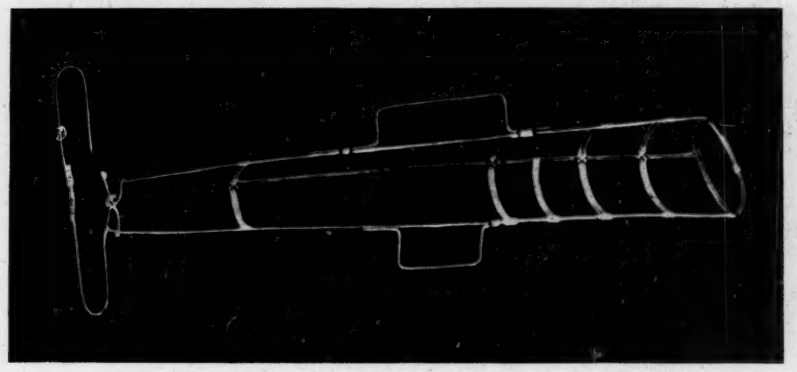


FIG. 47.—Skeleton splint with additional wires spliced to the side-bars, permitting windows to be cut in the latter.

this is easily made by shaping the back-bone, which is always necessary in splints for the lower limb, accordingly (see *Fig.* 46 A). Splints for the lower limb made of No. 2 or No. 3 gauge aluminium wire are sufficiently strong to support a limb of any weight; but to obtain the necessary rigidity, they require cross-pieces, which are made of aluminium ribbon half an inch wide and one-sixteenth of an inch thick, to hold the side bars and the back-bone together.

The disadvantage of aluminium is that one cannot solder it, so that the main part of the splint must be made out of one length of wire, and secondary pieces, like the back-bone, must be bound to the main frame; but the resulting splint is very light and strong, and the aluminium is so pliable that even when the splint is made up, it can often be manipulated to make slight alterations in its shape, which is impossible in the case of splints made of the iron wire, owing to its rigidity.

Unfortunately, it is not possible to obtain aluminium wire at the present time, owing to Government regulations, and Messrs. Rowat & Co. suggested

In *Fig.* 46 B I show an angled and telescoping wire splint that is of use in certain fractures of the lower limb; it is modelled after a splint, designed for closed fractures, which I described in my book *Fractures and their Treatment*, pp. 172 and 198. It is made with a long, fixed, unaltering leg piece; but the length of the thigh piece, which is the important segment, can be varied by three inches. *Fig.* 51 shows the same splint after it had been covered and applied in the case of an aged female patient with a rather unusual fracture of the shaft of the left femur. She had a long spiral fracture at the upper end, with great displacement of the fragments, as well as a comminuted fracture at the lower end of the shaft. She was treated by placing the limb in this splint, with a heavy extension (not shown in *Fig.* 51) applied in the axis of the flexed thigh, and, in addition, a light elastic extension on the leg. Excellent reposition of the fragments was obtained, with firm union of the bone. This type of splint is made in tinned iron wire, as soldering is necessary, and this cannot be done with the galvanized wire.

In *Fig.* 52 A I show a splint with a long open space at the back, which

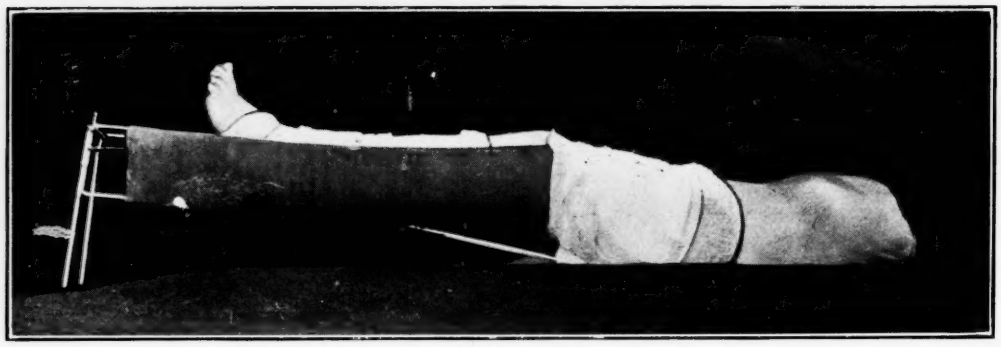


FIG. 51.—Skeleton splint shown in *Fig.* 46B, covered, and applied in a fracture of the shaft of the left femur.

may perhaps be of use in cases where continuous irrigation of a wound is required. A dam of waterproof material should be placed above the level of the wound, in order to check the upward flow of the irrigating fluid.

Measurements Required for the Splints.—It is important that the splints shall fit as accurately as possible, and the measurements I use are :—

1. From the perineum to the sole of the foot.
2. From the tip of the great trochanter to the sole of the foot.
3. From the gluteal fold, in the centre of the thigh, to the sole of the foot.
4. The oblique circumference of the thigh at the great trochanter.
5. The circumference of the limb at the knee, calf, and ankle.

The depth of the splint should equal the diameter of the limb—one-third of the circumference—so that the limb lies deeply in the trough formed by the splint for its entire length. The splint should be longer than the limb; its actual length will be determined by the length of the bed available for the patient. If the splint can be at least one foot longer than the limb it

is an advantage, as the extension, which I carry out by means of elastic tubing or cord, is more easily graded if the fixed point is some distance from the limb than if it is close up to the sole of the foot.

All the splints of this type for the lower limb require a back-bone, composed of a double wire, which can be opened out to make windows when required, as indicated in *Figs.* 46 and 49; its termination forms a convenient point to which to fix the rubber extension cords, which, when attached here, tend to brace up the whole splint and make it rather more rigid.

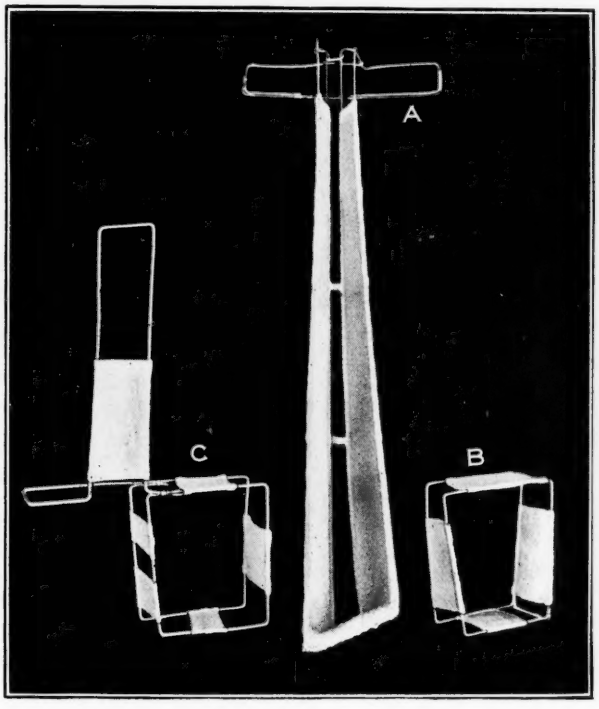


FIG. 52.—A. Splint for the lower limb with a long open space at back, for use in continuous irrigation treatment. B. Simple quadrilateral splint for injuries of the upper limb. C. Quadrilateral splint with forearm piece attached, made for the case shown in *Fig.* 56, where it is seen applied.

It has been found better for the foot-piece of the splint to turn backwards, as shown in *Figs.* 52 A and 46 B, instead of forwards, as at first made; it thus takes up less space in the bed, and is much steadier. The foot-piece may be made up any height, according to the degree of flexion of the femur that is desired, and is steadied by sand-bags when the splint is in use.

The body of the splint is made of two layers of lint (or flannel); the inner one, next the limb, should be looser than the outer, so that when the resin composition is poured on, the two layers shall come into close contact with, and adhere to, one another to form one piece, without any air spaces forming between them. Flannel shrinks more than lint, and this must of course be allowed for.

The ring is padded to the thickness of about an inch, then covered with jaconet, on the top of which a single layer of lint is placed. In this way a soft ring is obtained, as the layer of jaconet prevents the whole thickness of the padding absorbing the composition. Any irregularities on the surface of the ring are smoothed off with a hot iron or knife. The resin composition ought not to be too hot, because then it tends to run straight through the lint, rather than spread out in its substance.

SPLINTS FOR THE UPPER EXTREMITY.

For fractures of the upper limb I employ a wire splint having a quadrilateral shape; but instead of making it in the form of a trough, like the lower-limb splint, I find it better to make the supports, both for the upper arm and for the forearm, almost flat, rather in the form of a shelf, because the quadrilateral shape of the splint, as well as the method of attaching it firmly both to the trunk and limb, allow no chance for the latter to slip from position; more especially is this so when one employs extension. In consequence, about two-thirds of the circumference of the limb are freely exposed for dressing any wound that may be present on this surface, and if there be a wound on the remaining third of the limb which is in contact with the splint, a window can be cut in the support to give access to it (see *Fig.* 61); or, in certain cases, the support can be done away with completely, as the extension of the limb, and the bandages round it which are required to keep the dressings in position, will hold the part sufficiently steady.

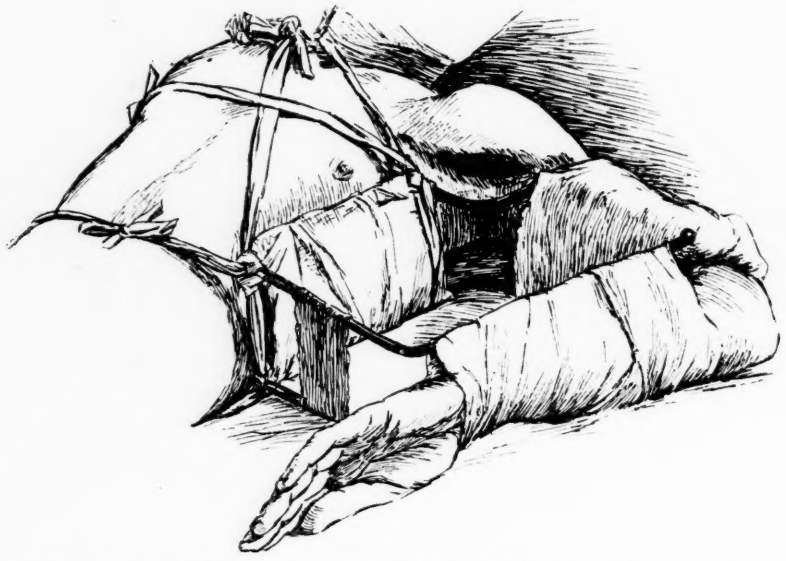


FIG. 53.—Large wound of the anterior wall of the axilla, with extensive destruction of the pectoralis muscle. The hand and forearm are in a position of pronation.

My primary splint for the upper limb is shown in *Fig.* 52 B. I have found this simple quadrilateral of great service in the treatment of a large number

of cases of extensive gunshot injury to the soft parts of the axillary walls, as well as to those over the scapular region, even where there was no bone involvement; because in these cases it is important to keep the muscles concerned in the movements of the shoulder-joint, and which may be themselves involved in the wound, at rest, and in such a position that when healing is completed, the power of abduction of the arm from the trunk will not be interfered with, as is certain to be the case if the arm be maintained at the side. As the abrupt turn of the splint, in its typical form (*Fig.* 52 B), may in some instances extend directly over a wound of one or other of the axillary walls,

FIG. 54.—Gunshot fracture of the humerus, with wide separation of fragments of the bone.

FIG. 55.—The same humerus as that shown in *Fig.* 54 after treatment in the abducted position with a quadrilateral splint.

it will sometimes be found necessary to modify the shape of the splint in order to obtain free access to the wound. In the case of an injury of either wall, the angle of the splint may be made concave opposite the wound, as in *Fig.* 53, or the upper posterior angle of the splint may be replaced by a circle round the wound, as shown in *Fig.* 57.

For cases of open fracture of the humerus, extension is obtained by adding to the primary splint a suitable outrigger of wire, as is shown in *Figs.* 57 and 59. The extension is obtained either by adhesive plaster attached to the limb, or by attaching the rubber cords to pins driven through the

condyles of the humerus (*Fig.* 59). Some of the men suffering from fractures of the humerus do not appear to be able to put up with any extension of the limb at all; in such cases I have found the primary quadrilateral splint alone is still useful; it has quite an efficient steadying effect upon the fragments of bone, provided careful bandaging of the upper arm and of the forearm to their respective supporting sides be carried out. The mere position of abduction in itself is, so far as one can judge from *x*-ray examinations, sufficient to give a fair re-adjustment and coaptation of the fragments (*Figs.* 54 and 55).

A point to bear in mind in dealing with extensively comminuted fractures of the humerus, such as so often result from gunshot wounds, is that movement of the distal main segment of the shaft, especially rotation, may—in consequence of the associated damage to muscle so often present—altogether fail to influence the position into which the proximal main fragment is thrown

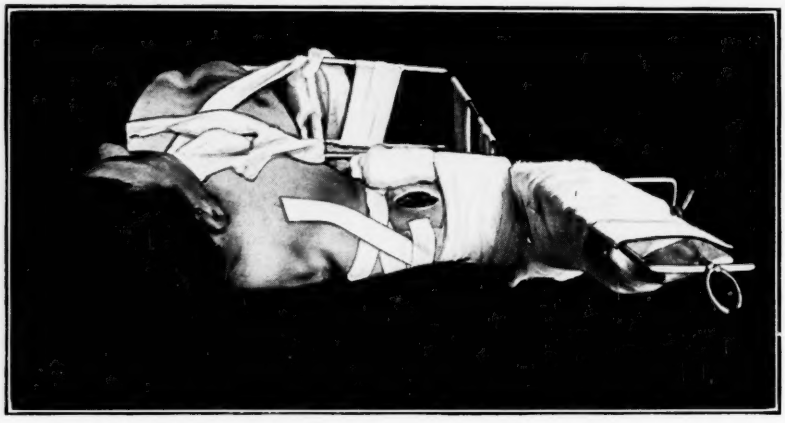


FIG. 56.—Gunshot fracture of the humerus treated with the splint shown in *Fig.* 52 C, to maintain complete abduction along with external rotation of the humerus, and at the same time to keep the limb extended. The posterior wound was free of the splint and accessible for the dressings.

by the unopposed action of muscles attached to it. In such cases, correct adjustment of the main fragments—and in these septic fractures the comminuted pieces must be left to themselves—can only be obtained by placing the distal fragment of the bone in the attitude which corresponds with that of the proximal one. Thus, in *Fig.* 56 the limb is shown abducted to a right angle, and at the same time rotated out at the shoulder so far that the forearm lies parallel with the trunk; for it was found, in the case of this patient, that this attitude gave the best reposition of the main fragments of the bone. The skeleton splint employed in this particular case is shown in *Fig.* 52 C. Here the forearm piece is made parallel to the trunk-piece; but the angle at which the forearm support is set with regard to the rest of the splint can easily be varied, so as to adapt the lower humerus fragment to the degree of rotation that will bring it into the best coaptation with the upper, uncontrollable, main fragment, as shown by *x*-ray screening and examination under anæsthesia.

In dealing with fractures of the upper extremity of the humerus, it cannot be too strongly insisted upon that the upper arm and the forearm must be adjusted at the correct angle both to one another and to the trunk; so that if ankylosis of the shoulder-joint—not an uncommon sequel in septic cases—is the best result that is to be anticipated, the arm shall ultimately be as useful as possible. The same remark applies to any fractures that may be complicated by a septic arthritis of the shoulder-joint.

This leads me to write of what I call the 'pitch' of the splint. In a large number of cases, perhaps the majority, it seems to me best to maintain the upper arm in the position of abduction at right angles during the process of healing; but this attitude will not always give the best coaptation of the fragments, so that it is necessary to decide at the commencement of treatment whether the arm shall be completely abducted or not. The position which gives the best reposition of the fragments must be chosen to start from. If this happens to be one that is less than a right angle, it may be possible to improve it as time goes on. For example, in cases where a wound involves either of the axillary walls, inflammatory exudation into the tissues might prevent—for the time, at any rate, and possibly permanently — complete abduction of the upper fragment; so that if one attempts to abduct completely the upper arm in these circumstances, it will result in angulation of the fragments at the site of fracture; if this be shown to be the case on screening, the arm must be abducted at such an angle that the fragments come into alinement. In *Fig.* 57 I show how the 'pitch' of the humerus side of the splint can be varied by arching the lowest, free side of the quadrilateral; by doing this, one of course approximates the forearm and trunk pieces of the splint at their lower ends, and so the angle which the support for the upper arm makes with the trunk piece can be altered to meet the posture which best brings the fragments into alinement. As improvement in the state of the soft parts takes place with stretching, absorption, etc., it may become possible

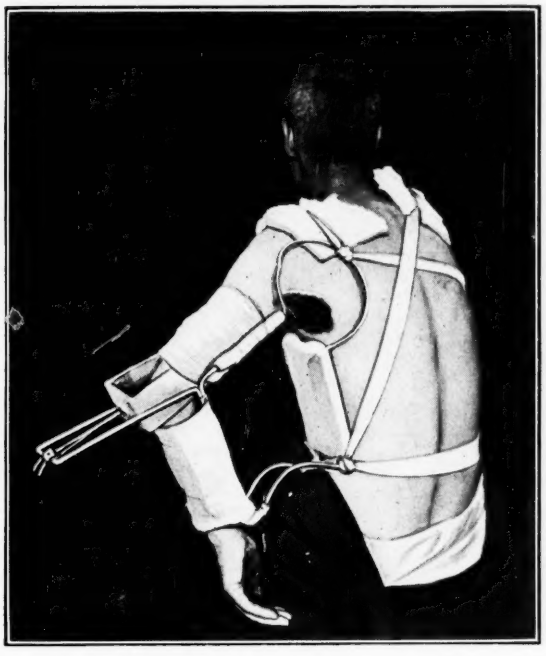


FIG. 57.—Cavernous exit wound after a perforating gunshot injury to the left arm. A comminuted fracture of the upper third of the humerus was produced, and the muscles of the posterior wall of the axilla were extensively destroyed. Free access is given for dressing the posterior wound. The anterior wound was free of the splint. The fracture was treated by extension together with 'position,' the humerus side of the splint being 'angled' to the required degree by arching the lower side of the splint.

to obtain more and more abduction of the proximal fragment of the bone, by gradually straightening the lower side of the splint and thus elevating the humerus support again.

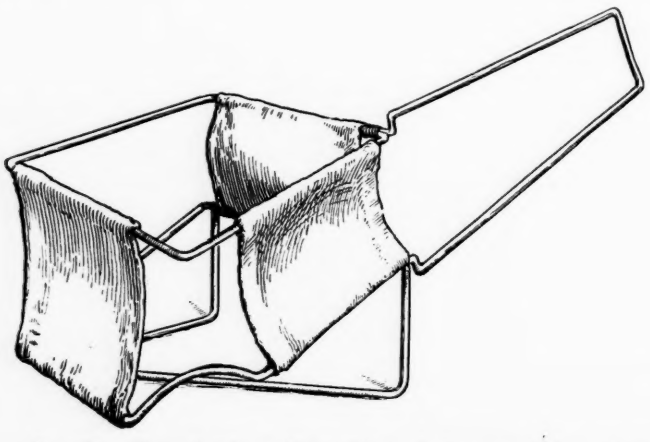


FIG. 58.—Skewed wire splint, with resin-impregnated supports for the limb, for maintaining abduction at the shoulder, along with flexion, in cases of fracture about the neck of the humerus. Extension of the humerus is provided for by splicing an outrigger to the main splint, the posterior wire of which is made concave at the axilla to allow access to a septic wound in the posterior axillary wall.

Another point in connection with the position of the limb, which generally concerns the fractures about the neck of the bone, is that it may be advantageous to keep the arm advanced, more or less, from the frontal plane, i.e., to keep it flexed at the shoulder-joint, while still maintaining it fully abducted. This can be allowed for in fashioning the skeleton wire splint, which for this purpose must be made skewed, so that the body-piece, which must lie parallel with the trunk of the patient, has the other three sides of the splint set to it at the angle which wil give the necessary flexion at the shoulder-joint. It necessitates, however, a firm support below the forearm piece, the patient being in bed; without it, the posterior wire which forms the posterior margin of the trunk piece, in consequence of the rotation caused by the weight of the arm and splint together, would be apt to press the skin unduly, and might cause a pressure sore; but with a support such as is shown in ***Fig.* 58** it is quite efficient. The further forward the arm is carried for this purpose, the more constrained does the attitude of supination become, and in such cases it is decidedly easier for the patient to have the forearm in a state of pronation (see ***Fig.* 53**).

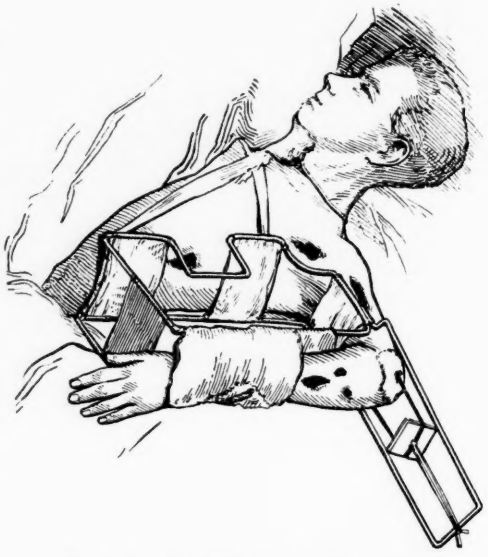


FIG. 59.—Quadrilateral splint, modified for application to a patient with a compound fracture of the humerus and additional wounds of the chest wall, axilla, and forearm, and with outrigger attached for obtaining extension. The extension is applied in this case by means of a pin driven through the condyles of the humerus.

The great advantage of employing wire in these splints is that any adaptation required for wounds, etc., in the shape of the splint, can be effected during their construction, and thus one is enabled to deal with practically any wounds that may be present, as well as with fractures. *Fig.* 59 shows a splint which I made for a patient who was suffering from (1) a septic fracture of the left humerus caused by a perforating gunshot wound (only one of the arm wounds is seen, the other being at the back of the limb); (2) a large wound involving the pectoral muscle in the anterior axillary wall; (3) another wound on the thoracic wall leading to fractures of the 7th and 8th left ribs; and (4) three wounds on the forearm. All of the wounds were highly septic. The patient was extremely ill from sepsis when admitted, and unable to sleep owing to the extreme pain in the limb, which was only supported on a wooden splint that required to be removed every time a dressing was necessary. My splint, along with the extension applied to the humerus, gave immediate relief, in consequence of the support it gave to the fracture; and all the wounds were made easily accessible for the necessary dressings.

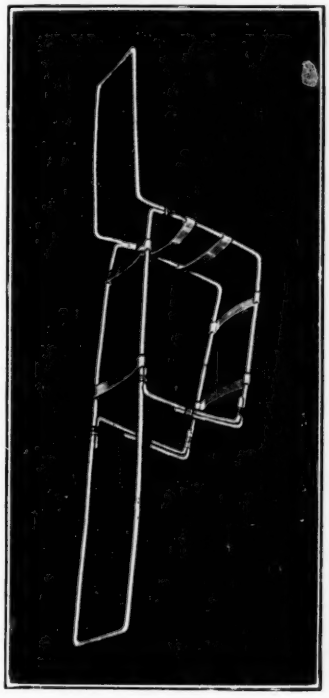


FIG. 60.—Skeleton splint for open fractures of the forearm bones. It is shown in application in *Fig.* 61.

For open fractures of the forearm bones I use a splint such as is shown in *Fig.* 60; *Fig.* 61 shows one of these splints in use. Extension is easily obtained, and the freest access can be given to any wounds that require dressing. When applied as shown in *Fig.* 61, with the palm of the hand lying against the splint, the forearm is in the attitude of complete supination (radio-ulnar). This position is of importance for many fractures of the forearm, however produced, whether in military or civil practice, but especially so in septic, comminuted, gunshot fractures; for, in this position, the shafts of the bone are kept as widely apart as is possible. Where there is considerable smashing of the forearm bones, I find it is easier to maintain supination, and more comfortable for the patient, if the composition support for the forearm is brought down far enough for the palm of the hand to rest upon. It is, however, just as easy to obtain a position of pronation (see *Fig.* 53), should it be found necessary and advantageous. I notice that where the forearm is left free, i.e., is not extended, the men wearing these quadrilateral splints frequently lie with the hand in the attitude depicted in *Fig.* 53, in complete pronation, as being an easy and comfortable one.

In fractures of the humerus where union is sufficiently far advanced, these splints, while still supporting the damaged bone, allow of free active movement being carried out at the elbow-joint, a point of very considerable importance in treatment.

Up to the present time I have not had any opportunity of testing the splint in a septic fracture of both the humerus and the bones of the forearm; but in a case of this kind, the extension could quite easily be applied to both segments of the limb by adding, for example, a humerus extension outrigger to the splint illustrated in *Fig.* 61.

Fig. 62 represents a telescoping and adjustable splint which Messrs. Rowat & Co. have made for me, and which is distinctly useful. It expands in each of its four sides from seven to ten inches, so that it will fit individuals with limbs which differ considerably in size; and it can also be angled as required to fit it to the displacement of the fragments of the humerus shaft; while its joints can be locked so firmly that the splint will remain perfectly rigid at any angle (*Fig.* 63). These appliances are especially useful as temporary aids in fixing a fracture until a lighter wire splint can be turned up to

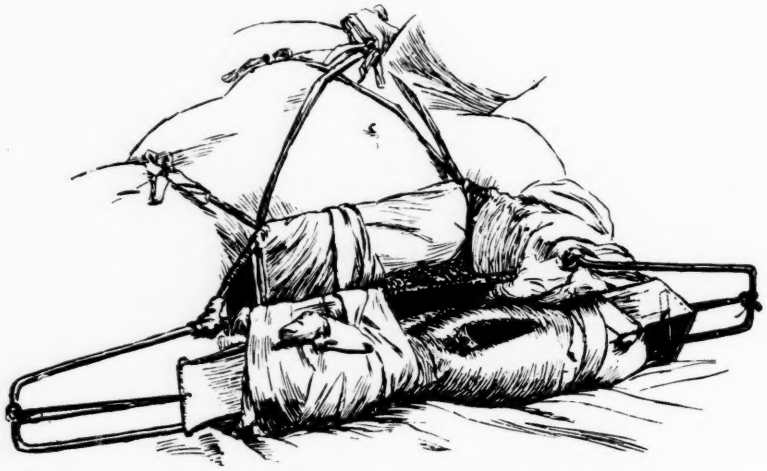


FIG. 61.—Perforating gunshot wound of the forearm, with extensive comminution of the radius. A window has been cut in the support for the forearm, to give access to the wound in the anterior aspect of the limb. The hand and forearm are in complete supination.

fit the individual patient. It is quite easy to add extension outriggers for the humerus or the forearm bones, either by wiring them to the main splint, or by having slots soldered on the latter into which the outriggers can be fitted. It is rather heavier than the ordinary simple wire splint, being made of thicker wire; it weighs, with lint and resin supports, $2\frac{3}{4}$ lb., as against the $1\frac{3}{4}$ lb. of the splint shown in *Fig.* 52 B, and this is almost its only disadvantage. It has been worn by men who had previously carried one of the lighter wire quadrilateral splints for several weeks, and they have assured me that it is perfectly comfortable and not at all too heavy.

It will be observed that nearly all the illustrations of the fractures of the upper limb show the splint applied to patients lying in bed. For my part, I believe patients with open fractures of the humerus are best treated lying down. As a matter of fact, when men suffering from gunshot fractures come to us, they are nearly all so seriously ill from sepsis that they cannot be in any other attitude. The splints may be a little awkward, but are no

bar to patients who wish to be up and about and who still require support for their fracture; if the man's general condition permits it, he quickly learns to steer his way fairly well even with one of these splints attached.

The various illustrations give a fairly accurate idea as to the measurements that may be required, but these vary so much in different cases that one cannot lay down definite rules.

I would only add, for the benefit of anyone who may desire to make the splints himself, that the measurements ought to be correctly made, and the calculated length of wire should allow for a certain amount over and above; and that, before making any bend in the wire during the construction of the splint, one should be quite certain of the correct plane in which it ought to go! In making arm splints, it is well to begin them at the cross-bar forming the lower extremity of the body piece (see *Fig.* 61), which may generally be taken as being about the centre of the length of wire required.

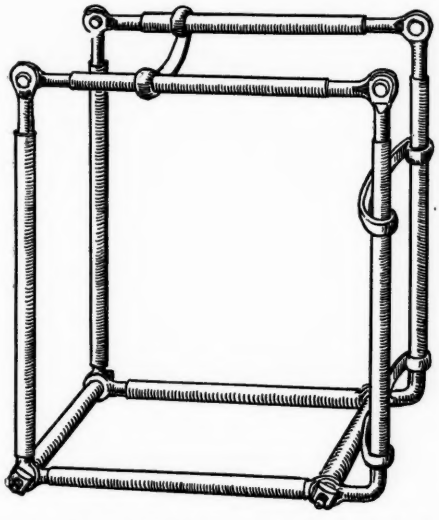


FIG. 62.—Telescoping splint, set at a right angle as for the right upper limb. Each side as shown measures 7 inches in length.

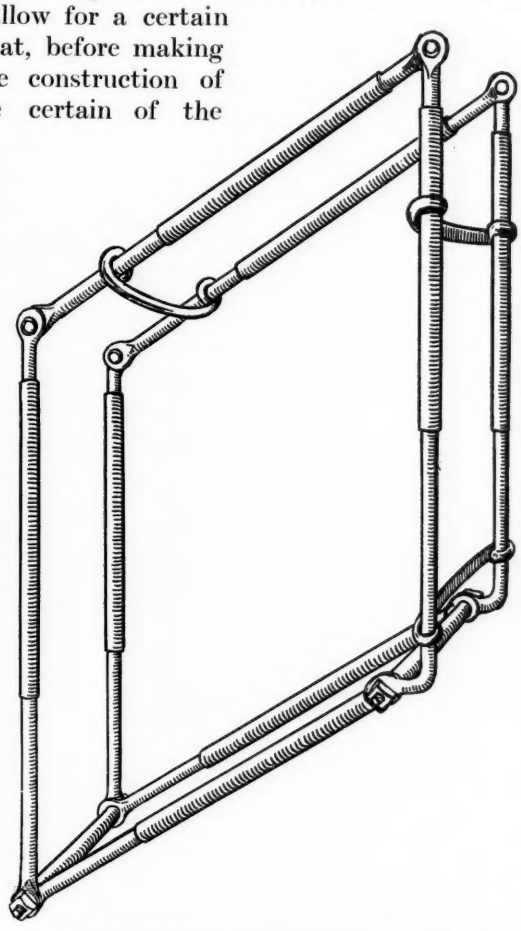


FIG. 63.—The same splint as shown in *Fig.* 62, set at an angle and locked by the locking nuts. Each side is here expanded to 10 inches.

A large number of the splints I have made up myself, but I desire to acknowledge the very great assistance received from Dr. T. Jackson, who was my house surgeon for nearly twelve months after the gunshot fractures came under observation. My thanks are also specially due to Miss J. B. Craig, the excellent sister of my wards, whose help in this, as in most of my work, has been invaluable.

THE CARREL TREATMENT OF WOUNDS.

By Colonel G. BARLING, A.M.S.

The essence of this treatment consists in the frequent instillation into the wound of a solution of sodium hypochlorite free from caustic soda.

The purpose is to destroy infection by constantly exposing it to the antiseptic, thus lessening the risks of septic absorption, shortening the process of healing, and enabling many wounds—whether simple, or associated with fracture or joint opening—to be closed by secondary suture.

It will be well first to say something as to the antiseptic now known as Dakin's fluid. With this article will be found a complete description of the preparation of the fluid devised by Dakin in collaboration with Dr. Carrel (for the translation I am indebted to Major Irwin, R.A.M.C.) Their aim has been to produce a solution containing not less than 0·45 per cent, nor more than 0·5 per cent, of hypochlorite of soda, the first being regarded as inefficient, the second as irritating. The presence of caustic soda is harmful because of the irritation it produces in the surrounding skin. To determine the presence or absence of this alkalinity, *powdered* phenolphthaleine is added to some of the solution; if caustic soda is present, the solution turns an intense red; whilst if it is properly compounded, there is no change in the coloration. Like all the hypochlorite solutions, Dakin's fluid is unstable, and must be protected from light, the best method being to use large receivers made of black glass, surrounded by wicker cases.

The antiseptic is carried into the wounded tissues by means of ordinary small rubber tubes, varying in size from about a No. 5 to a No. 10 india-rubber catheter. These tubes are closed at the end by a ligature, whilst they are perforated at short intervals by tiny holes made with a dental punch, the purpose being to retain some of the fluid in the tube, whence it will escape slowly into the wound; there is no intention to irrigate in the ordinary sense of the term. The minute lateral openings in the tubes extend over one, two, or more inches of their length, corresponding to the depth of the wound, or to its length if they are laid flat on the surface; if the openings cover an unsuitable length of the tube the fluid escapes outside the wound on to the skin, which is not desired. *Figs.* 64–67 show the distributing apparatus arranged for one, two, three, and four tubes respectively. If the wound is superficial, the terminal two or three inches of the tube may be surrounded with a thin layer of towelling, to help keep it in place. Again, if there is a cavity in the bone, a tube may be used the end of which is left open, and no lateral openings are made. The number of tubes used in a wound may vary from one up to eight or even ten. For instance, in treating a compound fracture into the ankle-joint, a group of about four tubes is usually sufficient; whereas with similar conditions at the knee-joint, when there is extensive injury to the bone, at

least about twice as many would be required when the early septic condition is attacked.

The tubes must be of such length as to allow of their being brought out through the dressing without bending or kinking. If one tube only is used, the antiseptic is most easily instilled by means of a small syringe such as that shown in *Fig.* 68, or the Koch syringe, but this must not be done forcibly; the same instrument may be used if there are multiple tubes, but economy of time is promoted by joining the tubes in groups to glass pieces with two, three, or four limbs,

FIG. 64.

FIG. 65.

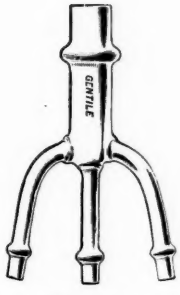


FIG. 66.

FIG. 67.

these in turn being connected with a single tube leading to a small reservoir (*Fig.* 69) containing the Dakin fluid, the supply to the wound being controlled by a small pinch-cock (*Fig.* 70) in the tube between the reservoir and the glass junction. The glass reservoir is suspended near the head of the bed, at a convenient height, and out of the way of injury.

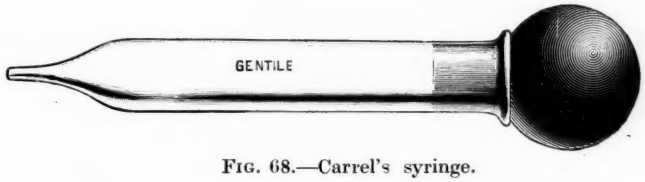


FIG. 68.—Carrel's syringe.

The tubes must be watched to determine whether the antiseptic flows evenly to all the branches so as to secure a general distribution to the wound. The amount applied every two hours depends upon the area of the wounded surface, but usually from ten up to thirty cubic centimetres are admitted at each instillation, according to the number of tubes and the extent of the wound.

The dressing materials used consist of small pieces of plain gauze about the size of the hand, and of pieces of Gamgee tissue or some similar material cut into portions of suitable size for the individual wound to be treated. In different clinics the details vary somewhat, and later on I shall briefly refer to these; but I may mention here that there is no packing of wounds with gauze in the sense in which this term is used in connection with salt packing. Absorbent cotton-wool, unenclosed between layers of gauze is not a suitable material for this method; it is difficult to handle, sticks on and around the wounded part and to the dresser's gloves, and takes up more time than, for instance, Gamgee tissue; this last point is a matter of some importance when a number of dressings have to be changed.

FIG. 69.—Complete apparatus for massive intermittent irrigation.

My first opportunity of seeing the Carrel method was at a hospital where Dr. Carrel has a clinic of somewhat less than 100 beds. Subsequently I had the advantage of also seeing Professor Tuffier's wards, and in his absence his cases were demonstrated by his assistant, Mdlle. Dr. Hartmann. At the same period I also attended the American ambulance in Paris under the direction of Dr. Hutchinson, and the Hôpital Buffon directed by Dr. Chutro. At each place I was most kindly received, and everyone was most willing to show me everything at their disposal, and to give me information on all points. I would like here to express my grateful thanks for the courtesy shown.

At Carrel's hospital there is the most complete demonstration not only of the clinical treatment, but also of its complement the bacteriological examination of the wounds, to which I refer later. An admirable illustration is also given of the clinical progress of wounds by means of the lantern. Photographs in colour are taken at various stages of the wound, the healing of which at different periods can thus be followed; and if the patient is still in hospital, a still later stage can be observed by the visitor.

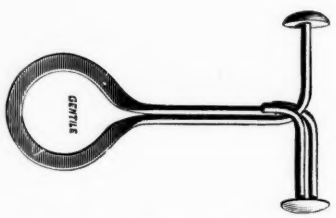


FIG. 70.—Mohr's pinch-cock.

The bacteriological method is quite simple. By means of a sterilized platinum wire a smear is taken from one or more parts of the wound, spread on a slide, and suitably stained. If it is a recent wound, the first examination usually reveals a large number of organisms of various kinds in each field of the microscope. About every two days this examination is repeated, and it may be that in the early stages the number of organisms actually increases; for instance, there may be thirty per field at the first examination, and at the

second sixty or infinitely more; but gradually the number of organisms per field drops, and at the end of ten days perhaps only five per field are found; a week later perhaps only one organism is seen in a field, to be followed by a further drop to one organism in four or five fields. If the clinical condition of the wound is in accord with the favourable bacteriological report, the time has arrived when the wound may be closed by suture. When this is possible, in cases of extensive gaps in the soft tissues, or in the presence of a compound fracture of an open joint, the advantages are great. Not only is the patient saved from the risk of secondary infections of his wound, but his stay in hospital may be materially shortened. The curve in the bacterial chart is not always in the direction of improvement; at times there may be a considerable jump in the record of bacteria found—sometimes without recognizable cause, at other times due to the removal of, say, a fragment of necrosed bone. The improving curve generally returns in a short time, and the normal fall to zero follows. Before closure of a wound, it is desirable to investigate more than one part of it, as the flora vary in different parts of the same wound. It is specially desirable to investigate secretions from any deep part or pocket; if the bacteria are fairly numerous on such an investigation, however satisfactory the remainder of the wound may be, closure should be deferred until the deep part shows better bacteriological results.

The technic of the dressings at Carrel's hospital is carried out with the most scrupulous care. The wounds are dressed every day, a course which is not followed everywhere. The surgeon is suitably clothed for his work, and wears gloves; he does not touch the wound even with his gloved hands, but removes the soiled dressings with two pairs of forceps, and uses the same instruments to readjust or replace the tubes if necessary, to apply pieces of gauze moist with Dakin's fluid, and over this to apply a layer of dry gauze. The skin for some inches around the edge of the wound is thoroughly cleaned with a fluid neutral soap, forceps holding a small swab being used for this purpose, as also to remove any excess of discharge from the surface of the wound itself. The outer pads of the special tissue are then brought together, and clipped with the forceps which have been used by the surgeon, who passes on to the next case, leaving a nurse to make a more permanent fastening of the dressing. To sum up, the dressing is carried out with as much care as though it were an operation on aseptic lines.

What are the results obtained by Dr. Carrel? The cases I had the opportunity of observing were *nearly all old cases* from other institutions, which I was assured arrived at Carrel's hospital after long suppuration—for weeks or months—and still suppurating. The records confirmed this. Many of these wounds were associated with considerable lesions of bone or joint. When the wounds were exposed by the removal of the dressing, I found that they were granulating beautifully, there was a complete absence of pus, and the only discharge was a semi-coagulated fluid looking like clear lymph or very thin glue. After one's experience of the prolonged suppurations in so many of the cases arising in the war, I felt that I was in the presence of successful wound treatment such as I had not seen approached by any other method.

The question arises: Is it possible for us to attain similar results in

English hospitals? In answering this, one has to bear in mind that Carrel's clinic is really an experimental hospital, provided with elaborate assistance in the way of laboratory, and medical and nursing staffs. The work is carried out by those who are through long experience intimately versed in the details—a really important matter—and as keenly interested in the success of the work as is their chief. The demands made by our hospitals upon surgeons and nurses, and the limited supply, render it impossible for us to have anything approaching the personnel of this Carrel hospital. In a busy time, such as occurred last summer, a great deal of dressing is of necessity left to the nursing staff, with supervision of the graver wounds by the surgeon. Does this render Carrel treatment in our hospitals an unsuitable method? Again, can we emulate in recent wounds the striking success attained in those of much older date? The answer to these two important questions is partly supplied by what I saw at some of the other hospitals, and partly by the experience I have so far had in the hospitals at Rouen.

At Chutro's hospital, the nursing staff is not so numerous as at Carrel's, though still more numerous than ours; but Chutro has so modified the method of dressing as to curtail the demands on the surgical and nursing staff to a very considerable degree. For instance, the dressing is not changed every day; the routine time is every second day, and in cases approaching their termination a longer period may be allowed to elapse. Again, no cleansing by soap is made of the skin around the wound; thus, in each dressing a few minutes are saved. It must also be remembered that in his hospital of some 300 beds, not a single splint is used to fix injured limbs, whether of the upper or of the lower extremity, whether associated with fractured bone or infected joint. In the lower extremity the limb is fixed by Chutro's extension-stirrup, passed through the tissues immediately in front of the tendo Achillis and above the upper margin of the os calcis; counter-extension is secured through the weight of the patient's body, by elevating the foot of the bed. The part is also steadied a good deal by the thick outer dressing devised by Dr. Chutro, and by a thin metal tray underneath the limb, which also prevents leaking of the antiseptic into the bed. The patient is kept very level by a strong fracture-board on which is superimposed a thick and very rigid but comfortable mattress. Whether Chutro's method of controlling the limb without splints is a good one or not, it undoubtedly facilitates dressing, and I saw no untoward results from discarding splints.

Chutro's outer dressing has much to recommend it. It is of large area: that for application to a high compound fracture of the femur would be split at its upper margin posteriorly and carried well over the buttock and the iliac region, and downwards to the knee or below. It is secured in position by ties of tape, no bandage being used. The dressing material is a very thick layer of good non-absorbent cotton-wool, with a thin layer of absorbent wool superimposed, the whole being enclosed between two layers of gauze or muslin. When the dressing is re-applied, the ties are undone, the outer covering falls open, the soiled gauze is removed, and the tubes are readjusted; but no cleaning of the skin around is attempted. Fresh moist, and then dry, gauze is applied, as at Carrel's hospital, and the covering is closed and tied again; or if it is

considered necessary, a fresh covering is used, a change required perhaps every time the wound is dressed, every fourth or every sixth day.

Dr. Chutro also reduces the bacteriological examination to a minimum. Wound films are not examined as a routine, but only in those cases which have reached the stage at which there is a prospect of being able to employ secondary suture; then the investigation is made over a period of several days. This is of course the really important time for the determination of the bacterial content of the wound, and in British hospitals we may well take a hint from Dr. Chutro, or the pathologists at the various hospitals will be overburdened.

In the late cases which formed the bulk of those seen at Carrel's clinic, little appeared to have been done in the way of opening up the wounds afresh, unless it was evident that some part of the wound was difficult of access or was pooling secretion; in such circumstances some enlargement of the existing wound was resorted to.

In the case of recent wounds a different course is required, and at Rouen we are working for the present on the lines I now mention. The wound is opened up freely so as to give ready access to all parts, and the damaged and badly infected tissues are removed as freely as the occasion requires and the position of the injury allows. If the injury is a fracture of the skull or a wound into a knee-joint such as we have been in the habit here of closing by immediate suture, that course would be adopted. If, on the other hand, the knee is too badly infected, or damage to the tissues will not allow of closure, Carrel's treatment would be begun at once, as it would be also in the case of compound fractures, or such wounds of the soft tissues without fracture as do not lend themselves safely to immediate suture. Counter-openings for drainage are not made, as they have the disadvantage of allowing the instilled fluid to escape almost as soon as it is introduced; but, on the other hand, much care is taken to remove all gross foreign material, and also all badly-injured tissue, not only in the soft parts, but also in the end of a bone entering into a joint. In the case, for instance, of a wound of one of the femoral condyles, a gouge, or a chisel and mallet, is used to get a clean surface of bone; but if there is a split into the femur, partly separating the whole condyle, the latter is not removed bodily. In the case of a compound fracture in the shaft of a long bone, the decision as to how much bone should be removed is not an easy one. If fragments are very freely removed it is easier to overcome the infection, and healing with or without secondary suture is secured at an earlier date; but such free removals are apt to be followed by failure of bony union. Several such failures of union have come under my observation. The general routine followed is to remove all entirely loose fragments, and to leave those which have some prospect of wholly or partly surviving. The wound having thus been thoroughly prepared, the instillation tubes are introduced in such numbers as will secure a thorough exposure to the influence of the hypochlorite solution, and the parts are supported by suitable splints. After amputation, Carrel's method may also be adopted, and in cases where there is no spreading infection from anaerobic organisms, flaps are generally made and loosely closed with sutures, and tubes are introduced freely, some being placed well into the larger areas of loose connective tissues between the muscles, etc.

The dressings are usually changed every day, unless an anæsthetic is required, when they are left two or three days. If the skin becomes sore and irritable around the wound, it is smeared with vaseline, which makes a good protection, or strips of gauze coated with vaseline may be applied. Skin irritation may be due to caustic alkali in the Dakin solution, and the solution should be tested to determine this.

It is too early yet to speak freely of the results obtained at the Rouen hospitals. The surgeons have so far had but a limited experience of Carrel's method, and the nursing staff are in the same position. There can be little doubt that familiarity with the details insisted on so emphatically at the Carrel clinic, is a very important element in obtaining the highest degree of success. Then, again, the wounds we have to treat at Rouen are much more extensive and severe than most of those seen at the clinics I visited; quite a number of our patients suffer from multiple wounds in different parts of the body, which again adds to the difficulties of treatment by both surgeons and nurses. It must also be remembered that the cases come to us in the full flush of their septicity, either to be treated primarily by Carrel's method here, or having a day or two previously been so treated at the casualty clearing stations. It is impossible to compare the course of such cases with that of the cases I saw at Carrel's hospital. It is most difficult to appraise accurately either the dose of sepsis the patient has received or his individual resistance to it; this should make us cautious in drawing wide conclusions from a limited number of happy results. With these reservations, I may now say that we have attained such a measure of success as I have not seen secured by other methods, and I anticipate that further experience will give still better results. A fair number of cases have been closed by secondary suture, mostly wounds of soft parts only, as we have been feeling our way with caution; but I anticipate that the future will provide greater opportunity for secondary wound closure.

It will be well for those who propose to adopt Carrel's method of wound treatment not to expect immediate miraculous results, but to remember the long period of plodding endeavour spent by the originator before he achieved his present success, and to remember also our long battle against sepsis during the whole of the present war. To ensure the best results, the surgeon must not only educate himself in the details, but he must take the trouble to train his nursing staff, so that they may have an intelligent understanding of his aims and be prepared with tubes, forceps dressings, etc., to facilitate his work and economize his time.

Those who have come in contact with Dr. Carrel, and who know his work, cannot be otherwise than deeply impressed by his results. In chronic cases, such as I have seen in such large numbers in the military hospitals in England, there seems no reason why we should not emulate the results obtained; but this can only be done if the surgical and nursing staffs of hospitals will take the trouble to understand the principles on which Carrel's work is based, and will attend diligently to all the details. In other words, there is nothing really difficult or abstruse about it; it is simply a matter of taking pains. For the majority of the surgical staffs who have no opportunity of visiting Carrel's or other clinics where this method is employed as a routine, an excellent guide

has been written by Carrel and Dehelly. It is entitled, "Le Traitement des Plaies Infectées," and is published by Masson et Cie, Paris, price 4 francs.

When we attempt to compare results obtained at British base hospitals in France with those at Carrel's clinic—that is, in the recently wounded—we have to bear in mind one radical difference between the two. At Carrel's hospital patients are frequently admitted within a few hours, six to ten, of being wounded. If the wounded tissues are then widely opened, and where necessary excised, and foreign materials removed, there is no gross infection to be combated, it has not had time to establish itself. Under these circumstances instillation of Dakin's fluid may be expected to give early sterility in the wounds. At our base hospitals the conditions are different; most of the patients have been wounded forty-eight hours or more before arrival.

The best results should be obtained at the casualty clearing stations, because there cases are received quite early. When moderate numbers of wounds are coming into these stations, they can be dealt with on the above lines, and transmitted to the bases in ambulance trains where the treatment can be continued.

[*Translation.*]

THE PREPARATION OF DAKIN'S SOLUTION.

(DAUFRESNE'S METHOD.)

Dakin's solution is a solution of hypochlorite of soda intended for surgical use, possessing the following characteristics, established after numerous trials and long experience in its use :—

1. *Complete absence of caustic alkali.* The absolute necessity of using in the treatment of wounds a hypochlorite solution deprived of caustic soda must completely put out of court Javelle waters (commercial), Labarraque liquor, and all solutions prepared by any other process than that about to be described.

2. The concentration of hypochlorite of soda is rigorously restricted to between 0·45 and 0·50 per cent. Below 0·45 per cent hypochlorite the solution is not sufficiently active; above 0·50 per cent it becomes irritant.

Chemical Products necessary for the Preparation.—Three are indispensable for the manufacture of Dakin's solution: chloride of lime, exsiccated carbonate of soda,* and bicarbonate of soda. Of these three products, the last two possess a practically sufficient constancy of composition; but it is not the same with the first, its content of active chlorine (discolouring chlorine) varying between very wide limits, and it is absolutely essential to titrate it before using.

Titration of Chloride of Lime.—To carry out the titration of chloride of lime, it is necessary to procure: A burette of 25 c.c. graduated in tenths of a c.c.; a graduated pipette of 10 c.c.; a decinormal solution of hyposulphite of soda.

This decinormal solution of hyposulphite can be obtained commercially ready-made (Poulenc); or one can prepare it oneself by dissolving 25 grms. of pure crystallized hyposulphite of soda in 1 litre of distilled water, and testing the solution by

* This product can be easily obtained commercially under the name of "Solvay Soda" or "Solvay Carbonate of Soda." If it is impossible to procure it, and only crystallized carbonate (crystals) can be obtained, it will be necessary (on account of the water of crystallization) to use 2·85 times more of the latter salt.

seeing that it discolours an equal volume of a decinormal solution of iodine, the latter obtained by dissolving 1·27 grms. of iodine and 5 grms. of iodide of potassium in 100 c.c. of water.

The material for the operation being ready, prepare a mean sample of the chloride of lime, which may be done either with a probe *ad hoc*, or by lifting from various points in the mass small quantities which should be carefully mixed afterwards.

Weigh 20 grms. of this sample, mix it as perfectly as possible with 1 litre of ordinary water, and leave for several hours, shaking it from time to time. Filter. Measure exactly, by means of the graduated pipette, 10 c.c. of clear liquid ; add thereto 20 c.c. of a solution of iodide of potassium (1–10) and 2 c.c. of acetic acid or hydrochloric acid. Let fall, drop by drop, into this mixture a decinormal solution of hyposulphite of soda until discoloration is complete. The number of cubic centimetres of the hyposulphite solution necessary to obtain discoloration, multiplied by 1·775, will give the weight of active chlorine contained in 100 grms. of chloride of lime. This figure being known, refer to the following table, which gives the quantities of chloride of lime, carbonate of soda, and bicarbonate.

Standard of Chloride of Lime	Quantities Required to Prepare 10 Litres of Dakin's Solution containing from 0·45 to 0·50 per cent NaClO		
	Chloride of Lime Grms.	Exs. Carbonate of Soda Grms.	Bicarbonate of Soda Grms.
20	230	115	96
21	220	110	92
22	210	105	88
23	200	100	84
24	192	96	80
25	184	92	76
26	177	89	72
27	170	85	70
28	164	82	68
29	159	80	66
30	154	77	64
31	148	74	62
32	144	72	60
33	140	70	59
34	135	68	57
35	132	66	55
36	128	64	53
37	124	62	52

Example.—If 16·6 c.c. of decinormal solution of hyposulphite are required to obtain discoloration, the titre (standard) of active chlorine in the chloride of lime tested is 16·6 × 1·775 = 29·7 per cent. The quantities to be used in this case to prepare 10 litres of solution will be :—

Chloride of lime	154 grms.
Exsic. carbonate of soda	77 ,,
Bicarbonate of soda	64 ,,

If there is only crystallized carbonate of soda at hand, it would be necessary to replace the 77 grms. of exsiccated carbonate by 220 grms. of the crystallized salt.

Preparation of Dakin's Solution.—To prepare 10 litres of the solution :—

1. Weigh exactly the quantities of chloride of lime, carbonate of soda, and bicarbonate of soda which have been arrived at in the course of the previous calculation.

2. Introduce into a 12-litre flask the chloride of lime and 5 litres of ordinary water, shake briskly for five minutes, and leave from six to twelve hours, say for one night.

3. At the same time dissolve, cold, in another 5 litres of water, the carbonate and the bicarbonate of soda.

4. Pour out at one operation the solution of salts of soda into the flask containing the mass of chloride of lime; shake briskly for a few moments, and then let it rest to allow the carbonate of lime which has formed to deposit itself. At the end of half an hour syphon off the liquid and filter it through a double paper in order to obtain a perfectly limpid product, which should be kept sheltered from the light. Light, indeed, changes solutions of hypochlorite fairly rapidly, and to preserve their effect it is indispensable to keep them from its action. The best way is to keep the finished liquid in large black glass carboys, encased in wicker.

Titration of Dakin's Solution.—It is well to verify from time to time the standard of the solution. This operation requires the same apparatus and products as those for determining the active chlorine in the chloride of lime.

Measure out 10 c.c. of the solution, and add thereto 20 c.c. of solution of iodide of potassium (1–10) and 2 c.c. of acetic or hydrochloric acid. Let fall, drop by drop, into the mixture, a decinormal solution of hyposulphite of soda until discoloration is complete. The number of cubic centimetres employed, multiplied by 0·03725, will give the weight of hypochlorite of soda contained in 100 c.c. of the solution. The solution is of a correct standard when, in the above operation, 12 to 13 c.c. of decinormal hyposulphite are employed to obtain discoloration :—

$$13 \times 0{\cdot}03725 = 0{\cdot}485 \text{ per cent of NaClO.}$$

Trial of the Alkalinity of Dakin's Solution.—It is easy to differentiate between the solution obtained by this process and the commercial hypochlorites and Labarraque liquid. Pour into a glass about 20 c.c. of the liquid to be tested, and let fall on the surface a few centigrammes of *powdered* phenolphthaleine. Dakin's solution, correctly prepared, gives absolutely no colour, while Javelle water and Labarraque liquor give an intense red colour, which indicates the presence of free caustic soda.

THE TREATMENT OF HÆMORRHAGE CAUSED BY GUNSHOT WOUNDS OF THE FACE AND JAWS.

By Major V. H. KAZANJIAN, Harvard Surgical Unit,
and Captain HAROLD BURROWS, R.A.M.C. (T.F.)*

Of the many complications which arise in the treatment of gunshot wounds of the face and jaws, secondary hæmorrhage is one of the most serious, and is a common cause of fatality. This fact has been emphasized by previous writers on war surgery, yet it is usually discussed in a general way, without definite analysis of its nature, frequency, and allied complications.

The following remarks are compiled from the records of 400 cases of gunshot wounds of the face with fracture of the jaws treated in the department of oral surgery at a general hospital where, between the dates of admission and of evacuation, sufficient time is given for comprehensive treatment and observation during the different stages of progress.

Condition of Patients on Admission to Hospital. — Though the maxillæ are the parts most affected, it can hardly be said that the injury is limited to these tissues alone. The missile is apt to cause comminution of many bones of the face, and to lacerate the eye, nose, ear, head, and submaxillary and cervical regions. Patients undergo a certain amount of mental shock, and are weak through fatigue, toxic absorption from the wounds, and lack of sufficient nourishment, the last being due to inflammation of the soft tissues and derangement of the organs of mastication.

Furthermore, a considerable proportion of cases have reached the hospital in a seriously ill condition because of additional injuries, such as penetrating wounds of the head and chest, fracture of the long bones, or multiple and extensive flesh wounds. Others have already contracted pneumonia previously to their admission.

All of these complicating circumstances have an influence on the mode of treatment employed when hæmorrhage ensues.

Frequency and Time of Hæmorrhage.—Of a total of 34 mild and serious hæmorrhages occurring among the 400 cases (8·5 per cent), 16 required operative measures for control under a general anæsthetic, while the remaining 17 were successfully treated by packing, clamping, or by the use of a local anæsthetic for ligation of the bleeding point. One case died suddenly from very profuse hæmorrhage.

The majority of secondary hæmorrhages took place between the fourth and twelfth days after injury, three between the thirteenth and nineteenth

* We desire to express our indebtedness to our colleague Lieutenant F. Brigham, of the Harvard Surgical Unit, for kind assistance in preparing this paper.

days, and only one after this period, namely, on the forty-fifth day (*Fig.* 71). In the last case both superior maxillæ and the base of the skull were fractured (*Case* 21).

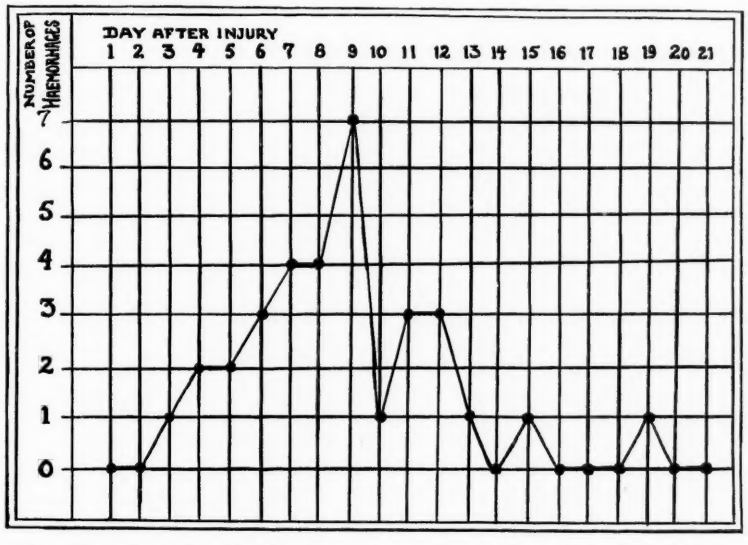


FIG. 71.—Chart showing the days of occurrence of secondary hæmorrhage.

It is interesting to note that most of the secondary hæmorrhages appeared during the night or early afternoon (*Fig.* 72); that is to say, during the hours of sleep. This is a curious fact, for it might have been expected

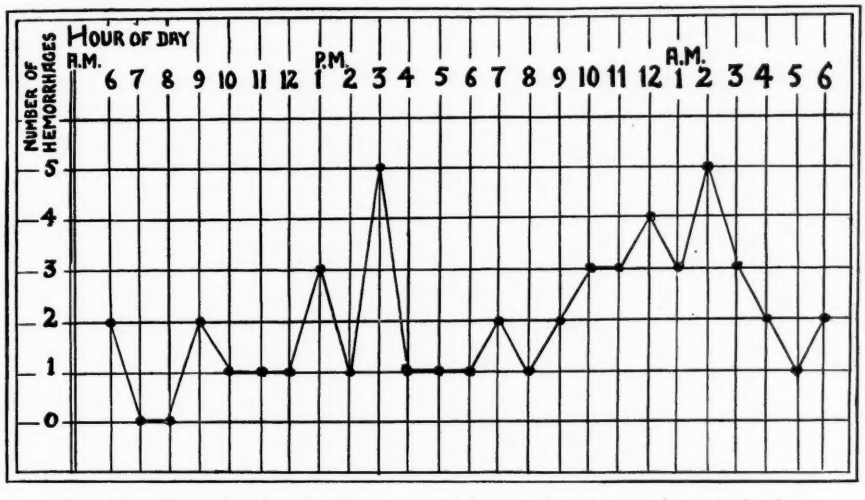


FIG. 72.—Chart showing the hours at which secondary hæmorrhage took place.

that the disturbances of feeding, dressing the wounds, taking impressions, or the fitting of appliances, would be the causes of recurrent bleeding from an injured vessel. Two cases of hæmorrhage have occurred within a few minutes

of the arrival of relatives at the bedside. Even if this were mere coincidence, it serves as a warning to minimize all likelihood of mental excitement on the part of any patient in whom bleeding is likely to occur.

The fact of the complication taking place at night, when the staff is attenuated, adds to the difficulty of treatment. The loss of blood may be profuse enough to bring on collapse with great swiftness, as in *Case* 29, where, though the medical officer was in attendance almost at once, the patient was already in a dying condition.

Sources of Hæmorrhage.—It is not always possible to determine the artery which is responsible. The surgeon is guided by a comparison of the anatomical distribution of the blood-vessels with the extent and direction of the entrance and exit wounds and with the injury caused to the soft tissues.

Injuries to the superior maxilla and other bones of the upper half of the face are often accompanied by nasal bleeding from the deeper structures,

FIGS. 73, 74.—Photographs (*Cases* 14 and 28) illustrating the type of case in which hæmorrhage is to be expected. *Fig.* 74 is a defective photograph, but it illustrates the appearance in question.

which arises probably from the branches of the internal maxillary artery. Amongst 91 cases of fracture of the upper jaw, there were four hæmorrhages: in three of these the bleeding was easily controlled by packing, while in the remaining one it was serious and persistently recurrent (*Case* 21).

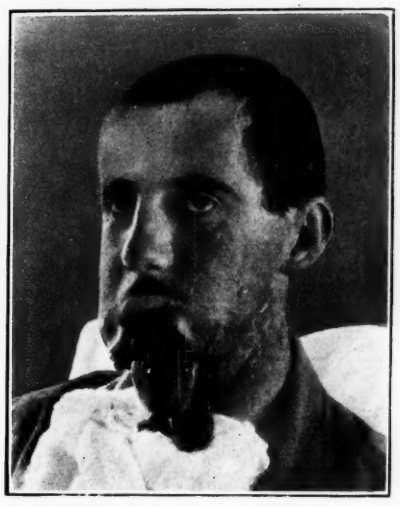
One case of bleeding from the anterior palatine artery has arisen, which was arrested by ligation under a local anæsthetic. Hæmorrhage from the main trunk of the internal maxillary artery is rarely or never met with.

In 7 cases of extensive laceration of the face, bleeding from the mouth has occurred. In all the hæmorrhage was superficial, with the source of bleeding exposed, and it was stopped by packing, by the application of clamps, or by the immediate ligation of the vessel under a local anæsthetic.

In those cases where the wounds are below or behind the angle of the lower jaw and involve the pharyngeal cavity and the neck, it is difficult to decide by internal examination which side is responsible for the bleeding. There were three such cases of hæmorrhage from the pharynx, two of which were fatal (*Cases* 25 and 29).

Bleeding which occurs as the result of extensive wounds of the molar and bicuspid section of the lower jaw, where there is an accompanying injury to the floor of the mouth, usually arises from the lingual artery or its branches. Such cases have been the most common, and likewise the most serious, as is shown by the fact that from a total of 34 hæmorrhages, 17 came from this source; and of this latter number, 12 required operative means of control under a general anæsthetic.

Certain cases which presage hæmorrhage from the lingual artery have recognizable characteristics. The wounds of entrance and exit are usually



FIGS. 75, 76.—Photographs of extensive injuries, illustrating cases in which serious hæmorrhage is not likely to arise.

small, and situated in the vicinity of the posterior half of the lower jaw. The tongue is perforated, often dark purple in colour, and swollen to twice or three times its normal size, so that in spite of the open position of the mouth, it protrudes beyond the lips. The jaw is fractured bilaterally, and the anterior segment shows a pronounced downward displacement. *Figs.* 73 and 74 are typical of the appearance of a case in which bleeding is to be anticipated.

On the other hand, large wounds anterior to the bicuspid region are unlikely to presuppose serious hæmorrhage, since the area affected is supplied only by smaller branches of the important arteries.

Extensive injuries, with destruction of the hard or soft tissues, but which are open, are less prone to bleed, because the free drainage forestalls the spreading of sepsis (*Figs.* 75, 76). Even with hæmorrhage from such a wound, it is usually possible to seize and ligate the vessel which is responsible.

Those perforating wounds of the neck which involve the pharynx are serious, in that irrigation and the establishment of drainage may be difficult, and the patient finds it an effort to breathe, to clear the throat, or to take nourishment, even with tubes.

TREATMENT.

This will be discussed under the headings of (1) *Preventive treatment*; (2) *Immediate treatment*; (3) *Operative treatment.*

1. **Preventive Treatment.**—Assuming that the recognized causes of hæmorrhage are—direct injury to the vessels, the spreading of sepsis due to the absence of free drainage, the presence of foreign bodies and splinters of bone, and mobility of the bony parts: then active measures should be taken to combat them. To overcome the uncleanliness caused by inflammation, suppuration, food deposits, and excessive salivation, the teeth and all mucous surfaces of the oral cavity are swabbed with cotton pledgets saturated with

FIGS. 77, 78.—Barton bandage.

tincture of iodine, followed by hydrogen peroxide; and then such solutions as potassium permanganate, boric acid, or listerine, are used to irrigate all parts of the mouth.

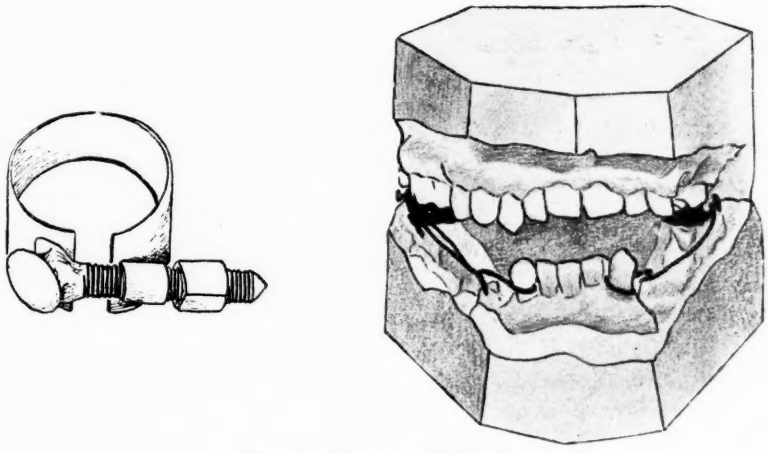
The removal of detached fragments of bone and affected teeth or roots is an essential factor in the control of sepsis. Infiltrative or conductive local anæsthesia about the oral cavity, with 2 per cent solution of novocain, may be employed through all stages of treatment; especially during the early days, when the consequences of general anæsthesia are to be avoided. The patient is more comfortable, and fed or dressed with less inconvenience, if he is kept in a semi-sitting position in bed. In the event of bronchitis or an irritating cough which tends to submit the muscles of the throat and face to undue exertion, immediate medical attention should be given. Liquid food

is administered through an œsophageal or a nasal tube; and if a pharyngeal injury prohibits this measure, rectal feeding is indicated.

In spite of the illness of the man, the jaw should have some sort of temporary support. This point is especially important, as it has been observed that the cases most prone to bleeding are accompanied by fractures of extensive displacement and mobility, with consequent enlargement of the wound and irritation to soft tissues.

The following are some of the simpler methods for securing comparative immobility of the jaw:—

The Barton bandage (*Figs.* 77 and 78) is an effective support when properly used. It is put on as follows: Starting a little to one side of the occipital region, the bandage is passed upward and forward across the head; it is then continued downward in front of the opposite ear, under the point of the chin, up the opposite side of the face, and diagonally to the back of the neck. Thence it passes around the neck below the ears, and across the chin to its starting point. After a part of the bandage has been put on in this



FIGS. 79, 80.—Angle's bands.

way, the horizontal turn which covers the chin may be modified to include wounds of the lips, nose, eyes, or forehead.

Angle's bands (*Figs.* 79 and 80), as manufactured for immediate use in cases of fractures of the jaw, can be fastened to selected teeth for attachment of temporary wire or silk ligatures. The displacement may be reduced by approximating the fragments laterally, or by anchorage to the upper jaw.

In other cases, brass wires (No. 25 American gauge) may be attached to the necks of opposing teeth and then twisted together; by leaving the ends uncut and emerging from the lips for four or five inches, the surgeon or attending nurse can untwist the wires to feed the patient or to clean the mouth (*Fig.* 81). The same end may be accomplished by twisting brass wires on to the teeth, with the ends cut short and turned over so as to form hooks between which small elastic bands are used to bring fragments of the jaw into approximate position (*Fig.* 82).

In any instance, if the facilities are at hand, dental splints or appliances should be used at as early a time as the patient's condition will permit.

In adjusting any splint, either temporary or permanent, the former occlusion of the teeth must serve as a guide, and any force applied must tend to reproduce this condition. The teeth existing on either side of the fracture serve as an anchorage, or if absent on one side, then the teeth of both upper and lower jaws are utilized.

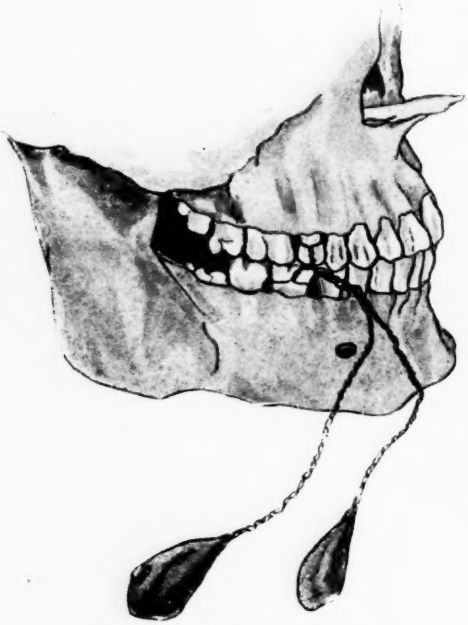


FIG. 81.—Jaws fixed by temporary wires, with ends of wires emerging from the mouth.

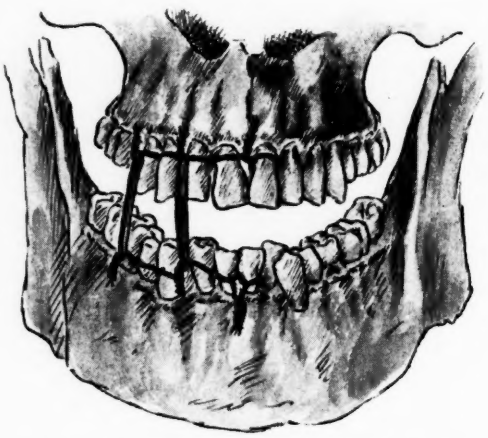


FIG. 82.—Jaws fixed by brass wires and rubber bands.

2. **Immediate Treatment.**—The seepage of arterial blood, which in most cases precedes a serious hæmorrhage, is almost the only anticipatory indication of value. Bearing this fact in mind, it is important that the surgeon should give the patient a careful examination immediately on admission, to determine the precise nature of the wound. Indeed, the exact area from which bleeding might be expected should be considered beforehand.

In the event of an emergency, the tray used in the ward for dressings may be depleted at the moment when it is most wanted, and therefore a separate one should always be kept in readiness, with swabs, ribbon gauze, artery clamps, sinus forceps, dental mouth-mirrors, a head-mirror, adrenalin chloride, hydrogen peroxide, etc.

As soon as the hæmorrhage appears, the attending nurse should send for the medical officer, and while awaiting his arrival, should syringe the patient's mouth with hydrogen peroxide, and attempt to control the bleeding with digital pressure. The patient should be kept sitting in bed against a back-rest, to facilitate the work, to reduce the blood-pressure in the head, and to prevent the flow of irrigating solutions and blood into the throat. The use of hydrogen peroxide gives a clean field of operation in the shortest time, and acts to a slight degree as a hæmostatic. Following this, the area is swabbed

rapidly, and that part from which blood issues is packed tightly with gauze soaked in adrenalin chloride.

As an adjunct to packing, a specially devised clamp will be found useful. This consists of a heavy piece of wire from eight to ten inches long, bent to a U shape, with a 'finger' or pad of dental modelling composition or vulcanite rubber on each end (*Fig.* 83). The clamp is adapted by bending it so that one end presses over the packing, while the other presses externally at a corresponding point under the chin between the hyoid bone and the lingual aspect of the mandible (*Fig.* 84). Ligatures or elastic bands about the arms of the clamp will give the desired amount of pressure. A clamp of similar pattern, but of reduced dimensions, serves for the arrest of hæmorrhage from the facial artery, exactly as one would pinch it with the thumb on the cheek and the forefinger inside the mouth.

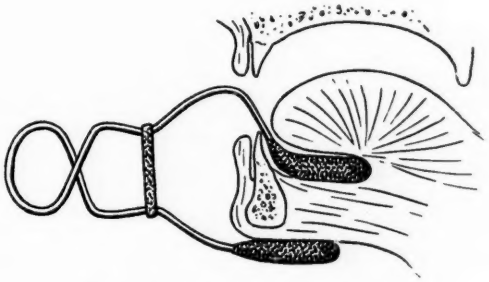


FIG. 83.—Lingual artery clamp.

It must be remembered that even though the act of packing may not be the final means of stopping the hæmorrhage, nevertheless it must be carried out to control it for the moment, and to minimize the chances of recurrence before ligation is effected.

3. **Operative Treatment.**—Suppose a case of recurrent or secondary hæmorrhage following a gunshot wound of the lower jaw; a case in which on account of its volume or frequent recurrence, the bleeding requires for its permanent arrest more conclusive measures than the fixation of the jaws and the packing of the wound; and let us discuss the operative treatment.

FIG. 84.—Patient with lingual artery clamp applied.

Three courses are open for consideration, namely: (1) *Ligation of the responsible vessel at the bleeding point:* (2) *Ligation of the vessel at some spot proximal to the bleeding point;* (3) *Ligation of the external carotid artery.*

Ligation of the common carotid artery is not included in the measure for cogent reasons. Although to secure the external carotid, with the patient in a desperate condition from loss of blood, is a difficult and perhaps protracted operation, and although there may arise in consequence a temptation to forgo the attempt and to tie the common carotid instead, because of the speed and ease with which this may be accomplished, nevertheless this expedient has been condemned entirely by experience. In the first place, we are often in doubt as to which side the

bleeding artery belongs. In the presence of such uncertainty, ligation of the common carotid is open to grave and obvious criticism. As a primary method of arresting hæmorrhage from the tongue or its neighbourhood, occlusion of this vessel is likely to fail in achieving success, owing to the abundant supply of blood in the external carotid through the collateral channels, including the circle of Willis. Moreover, the percentage of cases in which grave cerebral disorder has followed primary ligation of the common carotid is so high as to render the operation unjustifiable, except as an ultimate effort, when other means have failed. Probably the anæmia and shock which exist at the time of operation are largely responsible for the bad results. On four occasions we have been driven to tie the common carotid. Three of the patients died, and the one who recovered suffered from hemiplegia with aphasia (*Case* 23), a history which needs no further comment.

We will proceed to deal with the three legitimate operations which we have defined already, and will endeavour to separate the groups of cases to which each one has special application.

1. Ligation at the Bleeding Point.—The first proposal is to find and secure the bleeding point, for this is a rule of surgical practice established by the wisdom of our forefathers, and perpetuated by our own experience of its merit. This, which may be regarded as the ideal course, is available in certain cases, most of which are of lesser severity.

The following are the four varieties of cases in which an endeavour to secure the bleeding point is the correct practice.

a. Those in which the Bleeding is External.—Here the blood is not effused into the mouth, and the injured vessel may be sought for without any invasion of the buccal cavity. Injuries of the facial artery, or one of its branches, submental or coronary, provide most of the examples.

b. Intrabuccal Hæmorrhage of Small Volume.—In these cases the bleeding is not sufficiently profuse to obscure the field of operation, or cause much harm to the patient if allowed to continue during a brief local investigation. Such a hæmorrhage may come from an artery of the frenum, one of the palatine arteries, or some other small branch of the lingual, facial, or internal maxillary.

c. Copious Hæmorrhage from the Free Portion of the Tongue.—This arises from the ranine artery, and the bleeding is often alarming owing to the abundant flow. Temporary arrest, however, may be effected readily by placing a pad of gauze under the tongue, and pressing the tongue on the pad by means of a finger held firmly on the dorsum. The artery is easily accessible from the mouth for purposes of ligation.

d. Profuse Intrabuccal Hæmorrhage from the Floor of the Mouth when the Face is opened sufficiently to allow a good view of the Deep Tissues at the Base of the Tongue.—These cases are not common. The bleeding point can be looked for directly, because of the open nature of the wound. Another favourable feature is that the effused blood flows freely from the buccal cavity owing to the wide extent of the injury, and so does not cause the special difficulties which arise from the presence of a continual well of blood in the mouth.

One occasional source of difficulty in all these emergencies lies in the cessation of the hæmorrhage during operation; a contingency that is to be

expected if local anæsthesia be used, but which sometimes takes place also with general anæsthesia. Even rubbing the wound with gauze, and other local stimulation, may fail to reproduce the bleeding, with the result that the offending vessel cannot be located. Accurate observation of the wound while bleeding is still in progress may do something to mitigate this annoyance, but even careful preliminary investigation will not enable us always to avoid failure from this obstacle. The only remedy left is to examine the wound for any adherent clot, and by tracing it gently and minutely, endeavour to find the vessel from which it has originated.

FIG. 85.—Radiogram showing numerous fragments of shell, teeth, and bone scattered through the tissues.

2. LIGATION OF THE BLEEDING ARTERY AT A POINT PROXIMAL TO THE INJURY.—In cases where ligation of the bleeding point is impracticable—and in the majority of profuse intrabuccal hæmorrhages from the floor of the mouth such a course *is* impracticable—we have to adopt other tactics. Our first plan is to secure the injured artery at some point proximal to the seat of trauma. Here again, however, certain difficulties arise, the first of which is to recognize which artery is responsible. We have to consider eight possible

sources, four on each side—namely, the lingual, inferior dental, facial, and lastly, the external carotid itself, with its tonsillar, pharyngeal, and other branches. In some cases, especially where the entrance and exit wounds are small, we cannot definitely exclude any of these, either by anatomical study of the wound or by other means: for example, a through-and-through wound about the angles of the lower jaw. And even here, when some of the sources mentioned can be almost or quite excluded, we still are faced with sufficient doubt in trying to form an opinion as to the degree of responsibility resting on the remainder. Only too often we are quite unable to discover with certainty even from which side the hæmorrhage comes. Attempts to settle this seemingly simple question by arresting bleeding momentarily with pressure exerted alternately on the right and left carotids in the base of the neck, have failed.

FIG. 86.—Photograph of same patient as in *Fig.* 85.*

Anatomical considerations founded upon the situation of the wounds and the track of the main projectile are often vitiated by the fact that a bullet or fragment of shell, passing through the jawbone or striking the teeth, converts pieces of these tissues into secondary projectiles, which scatter and so cause damage to structures lying away from the main path (*Figs.* 85, 86).

Another complication which adds to the confusion is the occasional presence of simultaneous damage to two or more arteries. This association of injuries is not uncommon. The two lingual arteries are not far apart in the root of the tongue, and frequently participate in a common injury.

Broadly speaking, we may say that (*a*) Bleeding from the floor of the mouth comes from one or both lingual arteries or their branches; (*b*) Bleeding from between the fragments of a broken lower jaw arises from the inferior dental; (*c*) Bleeding from the cheek or lip has its origin in a branch of the facial; and lastly, (*d*) Bleeding from the pharyngeal and tonsillar regions will call for ligation of the external carotid artery.

If the lower jaw were intact, and the soft tissues in their normal relationship, this approximate localization would not be such a very hard matter. But in the cases under discussion the lower jaw is fractured—often in more than one place—and comminuted, while the tongue and other soft tissues may be much swollen by infiltration with effused blood and the products of

* In this case the right lingual and left external carotid were ligated in order to avoid hæmorrhage, although none had occurred previously to the operation. It is the only instance in which we have employed prophylactic ligature. The result justified the measure, for bleeding was to be anticipated, and the patient was so ill, that had operation been postponed until the hæmorrhage came about, there could have been little or no hope of saving his life.

inflammation. Moreover, as often happens in wounds of other parts of the body, the hole through which blood escapes may be remote from the point of vascular injury, to which it is then a false guide.

Again, a case which at one time appears simple may prove a dilemma. For example, the mandible is fractured at the bicuspid region, and blood is escaping from the cleft between the cheek and the alveolus. Is the facial or the inferior dental to blame?

However, these difficulties in locating the source of bleeding must not be exaggerated. They are considerable, but they do not rob anatomical estimates of all their value.

At first sight there might seem to be an easy way of avoiding all difficulties by ligation of the external carotid artery, because this would block the supply of all arteries of the same side which could be concerned with the trouble. After we had suffered some preliminary failures, and had met with cases in which bleeding recurred after ligation of the artery which we had thought to be the one concerned, we adopted this course of ligating the external carotid; but before long we had reason to revert to the former practice. We learned that ligation of the external carotid in these cases was attended by considerable difficulty and danger. We learned also that profuse recurrent hæmorrhage from the floor of the mouth nearly always arose from one or both lingual arteries or their branches. Consequently, our procedure in all copious hæmorrhages from this latter area, occurring in connection with gunshot wounds of the lower jaw, is to ligate one or both lingual arteries, provided the anatomical conditions are compatible with a wound of these vessels.

To assume that the lingual is the source, and to act on this assumption, may seem at first thought to be unsound: and probably most surgeons would feel inclined to hesitate before basing an operation upon such a guess-work diagnosis. However, improved results and a lowered mortality have convinced us that this practice is more than justified, and that it is indeed the right and proper method to adopt. Even when subsequent events prove that we have tied the wrong vessel, and another loss of blood points to the inferior dental as the source, probably we shall have avoided placing the patient's life in jeopardy; for bleeding from the latter artery, although it may be alarming, is not so copious as from the lingual, and is more easily controlled by packing while arrangements are being made to place a final check by a further operation. The following table shows the comparative results:—

Artery Ligated	Number of Cases	Deaths	Mortality
External carotid ..	10	5	50 per cent
Lingual	6	1	16·6 ,,

We have discussed the difficulties connected with this matter at some length, because the discussion maps out the road along which we have travelled ourselves, and therefore may be of assistance to others who journey in the same direction.

3. Ligation of the External Carotid Artery.—This is the final resort, and for more than one reason must be placed last on the list of available methods.

Experience has shown that ligation of the external carotid does not always finally dispose of the danger of bleeding. For, whether due to direct injury of a vessel of the opposite side, or to the collateral circulation which is so free in these parts, the fact remains that in a fair proportion of cases bleeding has recurred after ligation of the external carotid (*Cases* 2, 23, 28). Moreover, as will be seen later, ligation of this vessel in the presence of a compound fracture of the lower jaw due to a gunshot wound is formidable and dangerous.

OPERATIVE TECHNIQUE.

1. **Hæmorrhage from the Inferior Dental Artery.**—Analogy with the consequences of fractures of other bones would lead us not to expect recurrent hæmorrhage from the inferior dental artery after fracture of the lower jaw. However, we have had one case in which such an event certainly took place, and in which the bleeding was sufficiently persistent and profuse to endanger the patient's life (*Case* 9). This illustrates the great difficulty there may be in recognizing the source of a hæmorrhage. The lower jaw was fractured, and there was a gap in the alveolar margin through which the blood was escaping. We considered the possibility that this might come from the inferior dental, while, judging from the track of the wound, it might equally well come from the lingual or facial. The entry wound in the face was healed, and consequently, had the facial artery been responsible, the blood would have escaped through the buccal wound. At first we favoured the facial artery rather than the lingual, because the blood seemed to come from the outer side of the gap in the jaw, rather than the inner side. The recurrence of bleeding after ligation of the facial led us next to tie the lingual, for the volume of escaping blood was, as we thought, too large to originate from the inferior dental. And it was not until we had secured both the facial and the lingual, that we realized the actual source of the bleeding. It is probable, in view of the repeated recurrence of bleeding in this case, that the inferior dental had not been completely severed in the wound. This we could not ascertain, for in dividing the callus we divided the artery also.

Access may be obtained to the inferior dental artery by trephining the lower jaw-bone in the same manner as described in text-books for exposure and division of the inferior dental nerve. But we have not had occasion hitherto for adopting this manner of approach.

2. **Ligation of the Lingual Artery.**—The lingual artery arises from the external carotid near the hinder end of the great cornu of the hyoid bone. The first part is not overlapped by muscle other than the platysma, and extends from the point of origin of the vessel to the place where it passes under the digastric and stylohyoid muscles. The second portion is covered by the digastric and stylohyoid, and further forward by the hyoglossus. Both the first and second portions rest immediately upon the middle constrictor of the pharynx. The third portion passes up between the hyoglossus and the genioglossus, and upon reaching the free part of the tongue is continued on its under surface to the tip as the ranine artery.

Note must be made of the fact that the third part of the lingual artery is rather close to its fellow of the opposite side, from which it is separated only by the two flattened masses of the genioglossus muscles, an approximation which explains the frequent concurrence of injuries to both linguals in this region.

From the second portion arise one or more dorsal lingual arteries, which supply the dorsum and back part of the tongue and epiglottis. The third portion, that is to say the part lying in the floor of the mouth between the anterior border of the hyoglossus and the commencement of the ranine artery, is the source of most of the severe hæmorrhages with which we have to deal. In this situation the artery lies too deeply to be approached by operation from the neck; and we have mentioned already how difficult and unpractical it is to attempt to find the bleeding point itself in the floor of the mouth. The suggestion has been made that the vessel could be secured by passing a curved needle, threaded with ligature, deeply into the floor of the mouth, so as to include the third part of the lingual together with a substantial amount of the musculature of the tongue. Apart from the obvious objections to such massive ligation in a septic wound of the mouth, the plan is not likely to succeed in securing the artery, for anatomical reasons; the artery, its direction being upward and forward, is likely to elude the embrace of the ligature, unless a bulk of muscle be included which would be altogether inadmissible. Therefore we may dismiss as not feasible all operative attempts to arrest hæmorrhage by securing the third part of the lingual artery, by approaching it either from the neck or through the mouth. The ranine artery, as we have demonstrated already, may be caught without difficulty from the mouth (*Case* 10). Ligation of the first and second parts respectively, therefore, remains to be considered.

The incisions required for these two operations are different, and our own judgement as to whether we shall ligate the first or second part will be determined in many instances by the position of the external wounds. For we shall endeavour to place the operation wound as remote as possible from the gunshot wound, in the hope of thereby obtaining clean healing of the former. An additional factor comes into play. The dorsalis linguæ arteries arise from the second part, and if the tongue is wounded far back, we shall wish to be certain of securing these vessels, in which case we shall select the first part for the application of the ligature.

a. Ligation of the First Part of the Lingual.—With the patient supine, his face inclined to the opposite side, and the neck extended over a sand-bag, an incision is made along the anterior border of the sternomastoid, the centre of the incision being opposite the great cornu of the hyoid bone. The sternomastoid having been exposed, the deep cervical fascia is divided parallel with its anterior border. The carotid triangle is thus uncovered. Within this triangle are the external carotid artery and its branches. They are concealed, however, by areolar tissue, lymphatics, and certain veins, of which the common facial and the lingual, with their tributaries, chiefly concern us. There may be a temptation to try to expose the lingual artery by retraction of these veins. Unless, however, the exposure is quite easily accomplished in this way, it is better to divide and tie any veins that obscure our view. Time

ought not to be wasted in attempting to preserve any vein which lies in the way of a clear and unembarrassed field. The external carotid artery is now exposed, with the superior thyroid, lingual, and facial arteries successively arising from its anterior wall a short distance above the bifurcation. The landmarks that must now be identified clearly are: (1) The posterior end of the greater cornu of the hyoid bone; (2) The posterior belly of the digastric, with the stylohyoid muscle; (3) The hypoglossal nerve. All these are rapidly recognized (*Fig.* 87). The lingual artery is then traced upward and forward to where it passes deeply to the hyoglossus, stylohyoid, and digastric muscles. Two ligatures are applied at this point, and the artery is divided between them. The reason for tying the artery so far forward is to allow a sufficiently long stump between the proximal ligature and the external carotid artery.

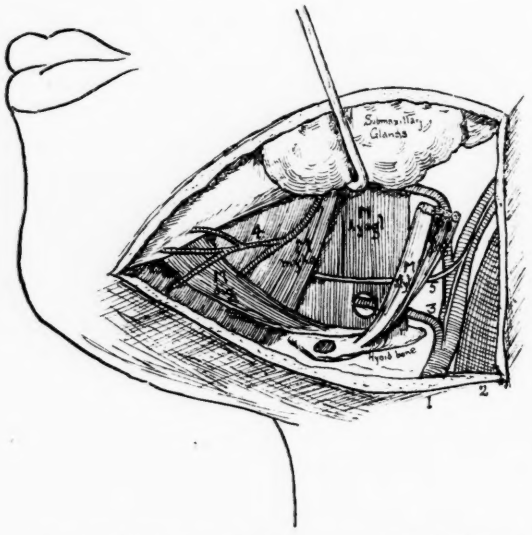


FIG. 87.—Diagram showing anatomy of the lingual artery. The submaxillary gland has been drawn over the side of the jaw with a hook. (1) External carotid artery; (2) Jugular vein; (3) Lingual artery (shown also in window in hyoglossus); (4) Submental branch of facial artery; (5) Hypoglossal nerve; M. dig. Anterior belly of digastric muscle; M. styl. Stylohyoid muscle; M. myho. Mylohyoid muscle; M. hyogl. Hyoglossus muscle; P. dig. Posterior belly of digastric muscle.

b. Ligation of the Second Part of the Lingual. — The patient is arranged on the table in the same posture as for ligation of the first part. A curved incision is made, commencing half an inch below the mental tubercle, passing downward and backward to the hyoid bone or the upper border of the thyroid cartilage—according to the amount of displacement of the jaw—and then upward and backward to the sternomastoid muscle. The flap thus formed is turned up, and the deep fascia is divided in the line of the original incision. The submaxillary gland is retracted upward so as to expose the floor of the submaxillary triangle, and the following landmarks are identified: (1) The anterior and posterior bellies of the digastric, with their intervening tendon; and (2) The hypoglossal nerve, lying on the hyoglossus muscle, and crossing the angular space between the two bellies of the digastric to pass under the mylohyoid muscle (*Fig.* 87). The hyoglossus is then cut through midway between the hypoglossal nerve and the greater cornu of the hyoid bone, the line of incision being parallel to the latter structure. This will expose the lingual artery, which is then tied in two places, and cut through between the ligatures.

SPECIAL DIFFICULTIES.—The displacement of the broken jaw and the swelling of the neighbouring structures lessens the freedom and ease of exposing the lingual artery in many cases, nor is one helped very much by

attempting to raise the lower jaw (*Figs.* 88, 89, 73, 74). In particular, the submaxillary salivary gland and the lymphatic glands in the submaxillary triangle are apt to form a solid, unyielding mass which lies in the way of a good view of the lingual artery. In some such cases retraction of these structures is unavailing, and it will then be found of great assistance to resect them: a manœuvre which does not materially lengthen the operation, while it greatly

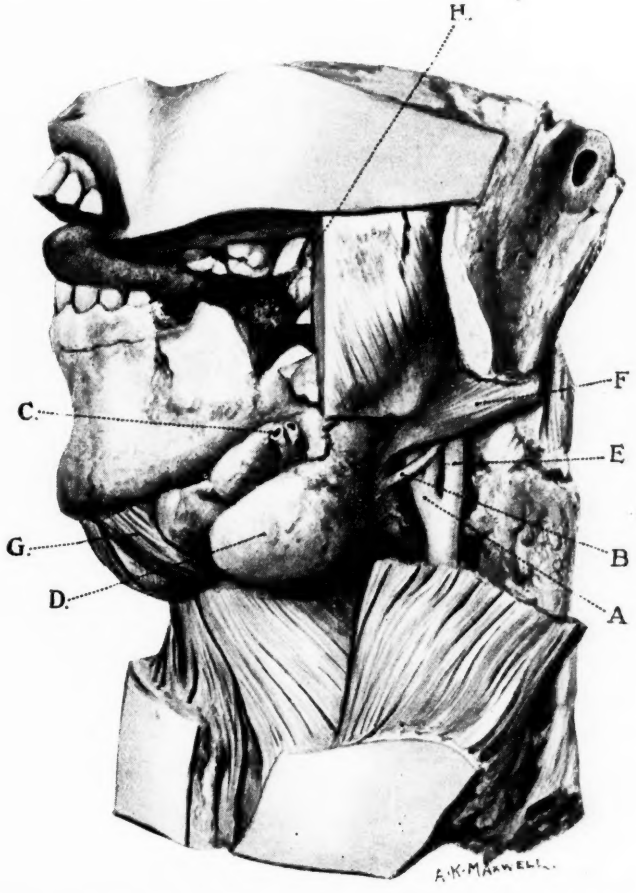


FIG. 88.—Drawing from dissection of a case of bilateral fracture of the mandible due to gunshot wound. The illustration shows the dropping of the anterior portion of the mandible, and the manner in which the glands overlap the submaxillary triangle and render it difficult to expose the second part of the lingual artery. (A) External carotid; (B) Hypoglossal nerve; (C) Facial artery and veins; (D) Submaxillary salivary gland; (E) Internal carotid; (F) Posterior belly of digastric muscle; (G) Anterior belly of digastric; (H) Clot protruding from the exit wound in tongue.

facilitates exposure of the lingual artery in the second portion. We have had to carry out this detail in two instances (*Cases* 7, 9).

Another trouble is the depth at which the artery lies. This can be countered by the assistant, who, with his hand placed on the other side of the patient's neck, presses the hyoid bone up into the wound.

On one occasion (*Case* 7), the second portion of the lingual artery could

not be seen after the hyoglossus had been divided. The first portion was therefore sought, and it was found that the lingual arose from the external carotid at a higher level than usual, forming a common trunk with the facial. In this position it was easily identified and secured.

3. **Ligation of the External Carotid.**—The incision and subsequent stages of this operation up to the point of exposure of the vessel, resemble those of the ligation of the lingual in its first portion, as already described. The spot usually chosen for the ligature is between the places of origin of the

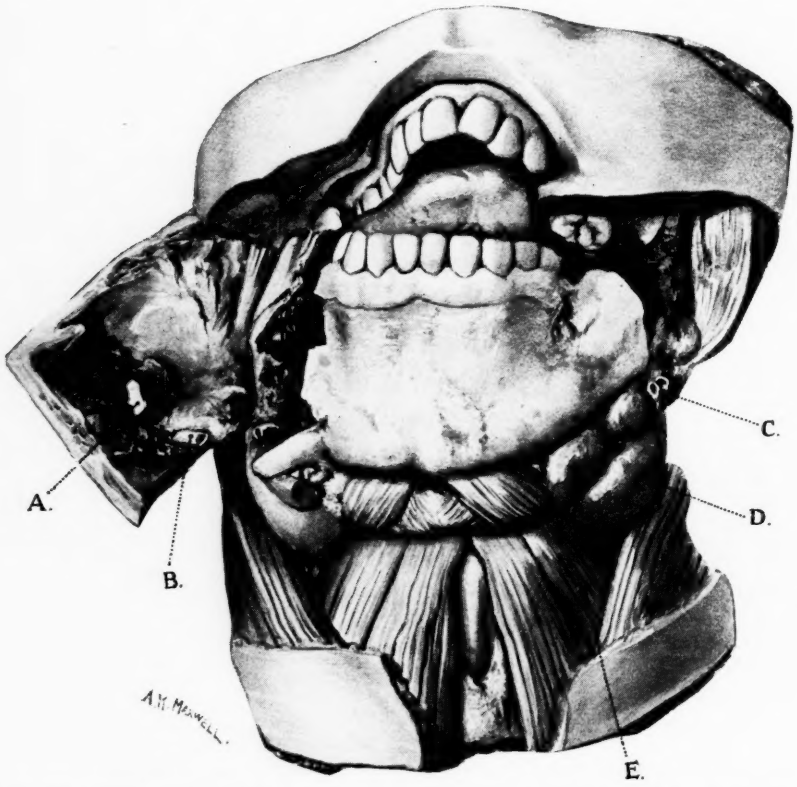


FIG. 89.—Anterior view of the dissection shown in *Fig.* 88. Shows the characteristic jaw-drop which follows bilateral fracture of the mandible. (A) Entry wound as seen from inner surface of reflected flap; (B) Facial artery completely divided in wound without causing secondary hæmorrhage; (C) Left facial vessels; (D) Submaxillary gland; (E) Omohyoid.

superior thyroid and lingual. But it may be well to tie the artery at a higher level than this—the lingual being tied off separately—in order to provide a longer stump between the ligature and the common carotid artery. The object of this is to avoid the protrusion of clot into the blood-stream of the common carotid, with the subsequent dangers of cerebral embolism. We had such a catastrophy in one instance (*Case* 30).

GENERAL DANGERS AND DIFFICULTIES.—There are certain drawbacks and difficulties in these operations for ligation of the lingual and external carotid arteries: and they deserve special comment.

Sepsis.—In the first place attention must be called to the fact that the operation wound is likely to become infected in a number of instances, owing to the proximity of the gunshot wound, together with the difficulty of keeping the operation wound dry during the ensuing days because of the continual dribbling of saliva in its neighbourhood. This consideration will lead us to make an incision, if we have any choice in the matter, as far away as possible from any pre-existing wound; and it may be the chief factor in determining whether to tie the first or the second part of the lingual.

Further, the possibility of sepsis ensuing renders necessary the application of two ligatures to the vessel concerned, which is then divided between them; otherwise, in a septic wound ulceration may set in, with a repetition of bleeding at the site of the ligature. Division of the artery between two ligatures permits retraction of the two ends, and forestalls this danger. We have had two examples (*Cases* 23, 25) in which secondary hæmorrhage occurred from the external carotid after the application of a single ligature, the artery having been left undivided.

Venous Hæmorrhage.—The chief difficulty in exposing the artery to be tied is due to the numerous large veins which intervene. Time will be saved and no harm done by the division of such as obscure our view. The common facial is the largest of them. The hindrance caused by these veins will be diminished if a free air-way is provided for the patient's respiration—a matter which will be discussed under the heading of "General Anæsthesia"—or if local anæsthesia be used.

All veins which are divided should be secured effectively before the wound is sewn up, because, in the absence of this precaution, there may be post-operative venous bleeding into the tissues of the neck, especially if the patient vomits. An additional precaution against this will be to remove the sand-bags from beneath the patient's neck, so as to relax tension and allow any unsecured veins to bleed before the wound is closed up. Fear of sepsis need not prevent us from suturing the deep fascia except where room must be left for drainage.

Displacement of Anatomical Relations.—There may be some disturbance of the normal relationship of the soft structures in the operation area through swelling from hæmorrhage or inflammation due to sepsis. But the chief displacement is the dropping of the jaw (see *Figs.* 73, 74, 88, 89). The elevators of the lower jaw are attached to the hinder portion of that structure, while the depressors are attached to the anterior portion. Consequently, in a double fracture of the mandible, which is not uncommon in these cases requiring operation for the arrest of hæmorrhage, the anterior portion of the jaw is pulled downward and backward. This dropping is not only a source of trouble to the anæsthetist (as will be mentioned again later), but is also a great inconvenience to the surgeon. The displaced jaw cannot be raised completely into its proper place by pressure applied to the chin or by traction on the incisor teeth, and the field of operation is therefore encroached upon. The necessity for excising the submaxillary gland when seeking to tie the second part of the lingual artery is chiefly due to this cause. And whether the external carotid or the lingual is to be ligated, one is apt to think at first that these vessels originate at a higher level than is actually the truth, and to

imagine that there is an abnormally high bifurcation of the common carotid—an error that is perceived as soon as the relative positions of the bifurcation and the upper border of the thyroid cartilage are examined (*Figs.* 88, 89).

Miscellaneous Drawbacks.—Probably it is well to avoid cutting into the lower portion of the parotid gland, though we have not observed any case in which this act has caused trouble through the escape of parotid secretion.

We have known a case in which the external carotid was wounded in the attempt to pass an aneurysm needle around it, with the consequence that the surgeon was forced to ligate the common carotid. We have also had a case in which the pharynx was perforated during an operation for ligation of the external carotid. Both the external carotid and the lingual arteries lie immediately upon the middle constrictor of the pharynx, and the latter is quite a thin structure. Consequently the danger of causing a pharyngeal fistula is not negligible.

We have referred already to cerebral embolism following ligation of the external carotid (*Case* 30), and also to the possibility of secondary hæmorrhage from the latter due to ulceration of its wall at the site of the ligature when the vessel has been ligated in continuity (*Cases* 23, 25).

Recurrence of Hæmorrhage from the Gunshot Wound.—This distressing sequel may be attributed to one of three causes: (1) We may have tied the wrong artery (*Cases* 2, 9, 23); (2) More than one artery may have been injured originally. The two lingual arteries come fairly close together in the mouth, and we have found both to be injured in more than one instance (*Cases* 14, 28, 30), and have suspected the coincidence in others; (3) The recurrence may be due to collateral circulation, in which case it is unlikely to be severe, and probably will be amenable to such simple measures as clamping or packing.

Shock.—Especial care must be taken to provide against shock. Owing to the severity of the original wound, loss of blood, and sometimes to concomitant injuries, these patients are liable to suffer severely and readily from shock. In a case where both linguals were tied, the patient died four hours later from this cause (*Case* 26). We have had other cases in which, although the patients did not die, the post-operation shock was considerable.

A word of warning is necessary with regard to the administration of morphia to patients who are suffering from the immediate results of copious hæmorrhage. This drug has an exaggerated effect on patients in this condition, and if any is given, it must be in smaller doses than those used for full-blooded persons. We have thought that the administration of morphia has another drawback, in that it seems to favour the development of bronchopneumonia—possibly by lessening the activity of the laryngeal reflex.

Bronchopneumonia.—One of the most serious complications of gunshot wounds of the jaw is septic bronchopneumonia. And the evidence is sufficiently clear that a frequent cause is the inhalation of septic material during anæsthesia. We believe also, as already mentioned, that morphia plays a similar part to chloroform or ether in this respect. Much of the danger of causing bronchopneumonia is avoided by employing local anæsthesia whenever possible.

General Anæsthesia.—The main precautions to be observed are two: (1) The avoidance of inhalation of septic material from the mouth into the respiratory passages; and (2) The provision of a perfectly free air-way for the patient, so that there will be no violent efforts to breathe, and no unnecessary engorgement of the veins of the neck to increase the length and difficulty of the operation.

To obtain the former end, the patient's mouth should be thoroughly cleaned and irrigated with antiseptic solution immediately prior to the administration. One hour before the operation, a hundredth of a grain of atropine is given hypodermically, to lessen the flow of saliva.

Anæsthesia is induced in the ordinary way until the patient is unconscious. The administration is then continued through two rubber tubes passed through the nostrils into the pharynx. The mouth is now thoroughly packed with gauze. By this means a free air-way is ensured, while the inhalation of blood and other material from the mouth is prevented (*Fig.* 90). Sometimes it may happen that the nostrils are too small to admit tubes of a sufficiently large size: one may then use an artificial air-way inserted into the pharynx through the mouth, which is then packed off with gauze around it.

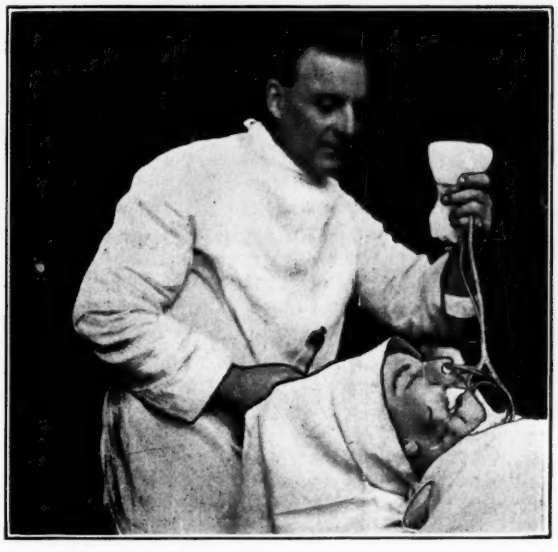


FIG. 90.—Showing the administration of an anæsthetic through nasal tubes.

During the preliminary stages of anæsthesia, the patient, supposing him to have a double fracture, may be unable to breathe freely unless the head and shoulders are supported. This difficulty will not grow less as the depth of the anæsthesia increases, and unless the cause and its remedy are known, very serious trouble may arise from impeded respiration. The cause is the displacement of the tongue and the anterior portion of the jaw; and the point to be realized is, that the tongue must be pulled forward and the jaw also. If the jaw only, or the tongue only, be pulled forward, there may be no relief: the traction must be on both. Failing immediate relief from this measure, the patient's head and shoulders must be well raised, when he will usually recommence to breathe. If not, tracheotomy should be performed without delay.

MORTALITY.

Of the 34 patients who had hæmorrhage, 7 died. This mortality is high. At first sight it may seem unduly high; but it must be remembered that, apart from the incident of bleeding, these patients were all suffering from grave

wounds, with other complications superadded to the vascular injuries. In more than one instance the patient already was in a desperate plight from loss of blood by the time that active measures for hæmostasis could be set on foot. *Case* 29 died from sudden and profuse hæmorrhage before assistance could be summoned. He had a wound penetrating the pharynx and tongue, and comminuting the lower jaw, and at the post-mortem examination the left external carotid and right lingual arteries were found both to have been wounded. The fatal hæmorrhage, we thought, had come from the former vessel. In *Case* 26, the patient died from shock within a few hours after ligation of both lingual arteries.

In the five remaining cases which ended fatally, operations had been performed for ligation of the external carotid artery. Of these, *Case* 8 died from recurrence of bleeding from the floor of the mouth, *Case* 30 from cerebral embolism, while *Case* 25 had secondary hæmorrhage from the external carotid at the site of ligature, and succumbed to shock after a second operation for ligation of the common carotid. In *Cases* 14 and 28, operations to secure the external carotid were not persevered with, and the common carotid was tied. Both of these patients died: one from shock, and the other from acute cerebral disorder.

PARTICULARS OF CASES.

Case 1.—Pte. G. C. T., wounded Sept. 15, 1916. Entry wound in region of left angle of mandible. Foreign body lying in right submaxillary region. Lower jaw comminuted at left angle. Tongue greatly swollen and perforated at root.

Sept. 20.—Operation to remove foreign body. Sept. 24.—Hæmorrhage from left side of floor of mouth; stopped by packing. Sept. 25.—Another hæmorrhage; left external carotid ligated. Good recovery.

Case 2.—Corpl. J. L., wounded June 19, 1916. Entry wound in right cheek at upper border of mandible in molar region. Exit wound in corresponding position in left cheek. Bilateral fracture of mandible in both molar regions, with much displacement of anterior fragment.

June 30.—Hæmorrhage from right floor of mouth; arrested by packing, followed by operation for ligation of right external carotid. July 3.—Hæmorrhage recurred: controlled by packing. Calcium lactate given. No further bleeding. Good recovery.

Case 3.—Pte. H. E., wounded July 1, 1916. Entry wound in left cheek at lower bicuspid region. Exit wound at right lower bicuspid region.

July 10.—Hæmorrhage from facial (?) artery; wound packed, and special clamp applied. July 11.—Slight hæmorrhage from left facial (?) artery; wound packed. No recurrence, and good recovery (the source of bleeding was uncertain, probably branches of the facial).

Case 4.—Pte. G. B., wounded Sept. 14, 1916. Entry wound in right lower molar region, and exit wound below and behind left ear. Fracture of mandible in right lower molar region. Perforation of tongue.

Sept. 21.—Hæmorrhage from the tongue; wound packed. No recurrence.

Case 5.—Pte. A. D., wounded by rifle bullet July 12, 1916. Entry wound in right upper lip. No wound of exit.

July 16.—Hæmorrhage from pharynx, with persistent coughing and difficulty in swallowing. July 17.—Operation; tracheotomy; jacket of bullet found lying against right thyroid cartilage. Rectal feeding for following two days. No recurrence of hæmorrhage. Good recovery.

Case 6.—Pte. T. S., wounded June 31, 1916. Extensive wound of lower lip. No exit wound. No foreign body retained. Lower jaw comminuted from right to left bicuspid regions.

July 16.—Two slight hæmorrhages from right side of mouth; wound packed and clamp applied. No recurrence.

Case 7.—Pte. L. E. M., wounded Oct. 7, 1916. Entry wound over angle of right lower jaw. Exit in left lower cuspid region. Comminution extending from left molar to right cuspid region.

Oct. 16.—Severe hæmorrhage from right side of floor of mouth; right external carotid tied. Uneventful recovery.

Case 8.—Pte. A. W., wounded July 5, 1916. Admitted to hospital July 11, suffering from bronchopneumonia. Patient had previously undergone flush amputation of right arm. Severe wound of face. Entry at right upper lip. Fragment of shell lodged just behind right angle of mandible. Fracture of right upper and lower jaws.

July 11.—Hæmorrhage from the mouth. July 17.—Anæsthesia given and foreign body removed; external carotid ligated as a precautionary measure; tracheotomy performed. July 19.—Another slight hæmorrhage. July 22.—Hæmorrhage; clamp applied. Patient died.

Case 9.—Rfmn. J. Q., wounded by rifle bullet Oct. 22, 1916. Entry wound in cheek just above lower right bicuspid region. Fracture of mandible at right bicuspid region.

Nov. 1.—Hæmorrhage from right side of mouth, which was packed. Nov. 9.—Hæmorrhage packed, and clamp applied. Nov. 10.—Slight hæmorrhage. Nov. 19.—Hæmorrhage; right facial artery ligated under novocain. Nov. 21.—Hæmorrhage; right lingual artery ligated under general anæsthetic. Dec. 5.—Hæmorrhage; jaw divided at site of fracture by cutting through callus; inferior dental artery occluded. No further bleeding, and uneventful recovery.

Case 10.—Pte. J. W., wounded by fragment of shell Oct. 22, 1916. Entry, large and lacerated, in right lower first molar region. Comminuted fracture of mandible from right molar to left cuspid region. Laceration of lip, tongue, and sublingual tissues.

Oct. 30.—Hæmorrhage from right ranine artery; bleeding vessel clamped and ligated without anæsthetic. Recovery without further hæmorrhage.

Case 11.—Sapper L., wounded Oct. 7, 1916. Wound of entry in right upper lip. Large piece of shell embedded in right cheek. Alveolar process of upper jaw fractured from right cuspid to left molar region.

Oct. 16.—Hæmorrhage from right facial artery, which ceased as soon as foreign body was removed. Oct. 19.—Second hæmorrhage from left anterior palatine artery; vessel ligated under novocain. No recurrence of hæmorrhage.

Case 12.—A.B. M. M., wounded Nov. 13, 1916. Entry in right lower molar region. Foreign body lodged in right side of tongue. Fracture of mandible in right bicuspid region.

Nov. 19.—Hæmorrhage into the mouth. Nov. 20.—Right lingual artery ligated. Recovery without further hæmorrhage.

Case 13.—Sergt. D. H. P., wounded July 2, 1916. Entry below right lower lip. Exit below angle of right mandible. Comminuted fracture posterior to right lower cuspid.

July 17.—Hæmorrhage from anterior portion of exit wound; operation to tie submental branch of facial artery. No recurrence.

Case 14.—Pte. H. C., wounded July 1, 1916. Entry in right cheek at lower second molar region. Foreign body lying behind angle of left lower jaw. Bilateral fracture of mandible. Extensive laceration of base of tongue (see *Fig.* 73).

July 7.—Foreign body removed. July 8.—Hæmorrhage occurred, which was packed; a second hæmorrhage later in the day. July 13.—Profuse bleeding recurred; an operation to tie the external carotid was not feasible, and the common carotid was ligated. Patient died from shock a few hours later. Post-mortem disclosed bronchopneumonia in both lungs.

Case 15.—Pte. A. S., wounded Sept. 30, 1916. Entry wound in left cheek at region of first molar. Large exit wound at angle of right lower jaw. Bilateral fracture of mandible.

Oct. 9.—Hæmorrhage from branch of right facial; vessel secured in the wound. No recurrence.

Case 16.—Pte. R. J. L., wounded Sept. 13, 1916. Entry wound below centre of lower lip. Exit wound in back of right neck, at level of 6th cervical spine. Paralysis of right arm, due to injury of anterior primary division of the 5th cervical nerve.

Sept. 20.—Hæmorrhage from inferior region; treated by packing. No recurrence.

Case 17.—Pte. F. J., wounded Sept. 14, 1916. Entry wound one inch below left ear. Exit below first right lower molar. Perforation of tongue.

Sept. 21.—Slight hæmorrhage from tongue; controlled by packing. No recurrence.

Case 18.—Sergt. W. I., wounded July 1, 1916. Entry wound below right corner of mouth. Exit just behind left angle of mandible. Bilateral fracture in right cuspid and left third molar regions.

July 20.—Hæmorrhage, probably from left inferior dental at site of fracture; controlled by repeated packings. No recurrence.

Case 19.—Pte. S. D., wounded July 1, 1916. Extensive superficial wound of right side of face and mouth, with comminuted fracture of mandible in right bicuspid region.

July 13.—Hæmorrhage from external wound; artery exposed in wound under local anæsthesia, and ligated. No recurrence.

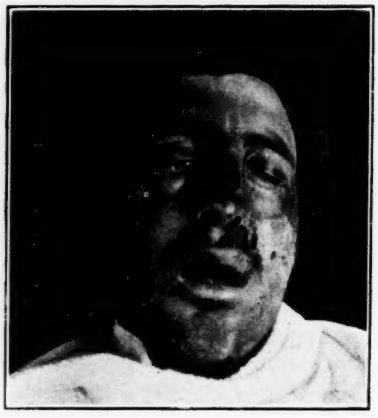


FIG. 91.—*Case* 21.

Case 20.—Pte. R. C., wounded April 26, 1916. Entry wound right side of face over zygoma. Exit in lower bicuspid region. Right upper jaw fractured.

May 4.—Hæmorrhage from nose; packed. No recurrence.

Case 21.—Pte. A. W., wounded Sept. 27, 1915. Small wound of entrance above left angle of mouth. No exit wound. Fractures of left malar bone, nasal bones, both superior maxillæ, and the lower jaw (in three places), also probably base of skull (*Fig* 91).

Nov. 12.—Hæmorrhage from nose and into nasopharynx; nostrils packed. Numerous recurrences from Dec. 2 to Dec. 16. Evacuated to England at patient's own request before we were certain that the recurrence of bleeding was no longer possible.

Case 22.—Pte. H. L., wounded Oct. 12, 1915. Entry wound at left corner of mouth. Exit in right lower molar region. Comminution of mandible from one molar region to the other. Laceration and swelling of tongue (*Fig* 92).

Oct. 20.—Hæmorrhage from floor of mouth; right external carotid tied. Good recovery.

Case 23.—Pte. F. D., wounded March 15, 1916. Entry wound left corner of mouth. Exit at angle of right mandible. Perforation of tongue.

March 22.—Hæmorrhage from root of tongue; left external carotid tied, which did not stop the bleeding; repeated packing, and application of clamp, checked hæmorrhage. April 9.—Secondary hæmorrhage from left external carotid at place of ligature; common carotid and internal carotid ligated. Operation followed by hemiplegia.

Case 24.—Pte. J. W., wounded July 3, 1916. Entry wound one inch to right of nose. Exit wound in front of lobe of left ear. Hard palate perforated.

July 8.—Bleeding from nose; nostrils packed. No recurrence.

Case 25.—Pte. P. L., wounded Sept. 15, 1916. Entry wound over angle of right lower jaw. Exit just below angle of left lower jaw. Right mandible fractured at angle. Pharynx perforated.

Sept. 19.—Hæmorrhage, source of bleeding uncertain; wound too far back to be packed; rectal feeding employed. Sept. 25.—Hæmorrhage; right external carotid ligated. Oct. 4.—Secondary hæmorrhage from external carotid at site of ligature; common carotid tied. Left hemiplegia developed, and patient died two days later.

FIG. 92.—*Case* 22.

Case 26.—Pte. G. G., wounded July 13, 1916. Entry wound in left bicuspid region. Exit in right cheek, exposing alveolar processes of upper and lower jaw. Right side of mandible destroyed in bicuspid and molar region, and comminuted fracture present in left bicuspid region.

July 19.—Hæmorrhage; both lingual arteries tied in the floor of the mouth; the external wound was sufficiently extensive to permit this. Patient died of shock a few hours later.

Case 27.—Capt. W. H. S., wounded Sept. 15, 1916. Projectile entered left scapular region, emerged from left neck, and struck the lower margin of the mandible on the left side one inch in front of the angle, causing an extensive wound of the lower face from the point of entry to the middle of the lower lip. Lower jaw completely destroyed from left molar region to right bicuspid region. Much laceration of the sublingual tissues.

Sept. 28.—Hæmorrhage from sublingual region; packed. Several recurrences occurred, which were successfully treated by packing.

Case 28.—Co. Sergt.-Major H. B., wounded July 29, 1916. Entry wound in left face at angle of mandible. Large wound of exit in corresponding region of right side. Bilateral fracture of lower jaw at both angles. Tongue lacerated and swollen (see *Fig.* 74).

Aug. 7.—Hæmorrhage from left side of mouth; operation for its control; ligation of common carotid necessary; no direct cerebral complications. Aug. 8.—Hæmorrhage from mouth; right external carotid ligated. Patient died after a few hours.

Case 29.—Capt. E., wounded Nov. 13, 1916. Entry wound in left mastoid region. Large exit wound extending from right corner of mouth along lower border of right mandible. Laceration and swelling of tongue.

Nov. 21.—Severe hæmorrhage occurred, and patient died almost immediately.

Case 30.—Pte. L. D., wounded Oct. 14, 1916. Entry wound at middle of chin. Fragment of shell lodged subcutaneously in left side of neck over sterno-mastoid. A fragment of bone formed a secondary projectile, which penetrated deeply into the floor of the mouth. Fracture of mandible at symphysis.

Oct. 23.—Hæmorrhage from floor of mouth. Oct. 25.—Right external carotid tied. Oct. 27.—Left hemiplegia developed suddenly, with dilatation of left pupil and laryngeal paralysis. Oct. 30.—Patient died.

Post-mortem Examination.—Embolism of right middle cerebral artery, with softening of brain, most marked in right internal capsule. The stump of the external carotid was filled with firm clot, which, however, extended down into the common carotid. There was a fragment of bone lodged against and displacing backward both lingual arteries, which were partially torn across. Multiple foci of suppuration were present in both lungs (inhalation pneumonia).

FIG. 93.—*Case* 31.

Case 31.—Pte. H. L. M., wounded Aug. 5, 1916. One large lacerated wound of lower lip, chin, and sublingual regions, with comminuted fracture extending from one molar region to the other (*Fig* 93).

Aug. 16. — Hæmorrhage; lingual artery ligated directly at bleeding point. No recurrence.

Case 32.—Lance-Corpl. J. L., wounded Oct. 23, 1916. Entry wound at edge of left upper lip. Large exit below and behind right angle of mandible, exposing the external carotid artery. Right lower jaw fractured at the angle.

Nov. 4.—Severe hæmorrhage from right facial artery at a point half an inch from its origin from the external carotid; vessel ligated at bleeding point; right lingual also ligated. No further hæmorrhage.

Case 33.—Pte. W. M. G., wounded Oct. 13, 1916. Entry wound in left lower molar region. Exit at left corner of mouth, where there was extensive laceration. Comminution of left lower jaw from molar to cuspid region.

Oct. 18.—Hæmorrhage from branch of left facial artery; treated by packing.

A REPORT ON ORAL AND PLASTIC SURGERY AND ON PROSTHETIC APPLIANCES.

By Major A. C. VALADIER, C.M.G., R.A.M.C.(T.H.C.),
and Captain H. LAWSON WHALE, R.A.M.C.(T.)

MAJOR VALADIER'S REPORT.

Recent medical literature has contained many monographs on the treatment of fractured jaws. Some of these are remarkable for their length rather than for their addition to our knowledge of the subject. Others are richer in scientific interest, but as contributions to war surgery their technical value is discounted by the point of view adopted by the authors, for they seem to approach the subject as if they were dealing with fractures as they occur in civil practice. This attitude not only fails to help those who may wish to study the subject, but may mislead them; for the treatment of jaws fractured in war is very different from that of injuries received in peace-time; and only those who have handled a large number of cases can give reliable guidance.

In July, 1916, an English medical journal published an article wherein the author stated that "The great number of jaws fractured in this war could be so treated that the patients should be back in the firing line in five or six weeks." I can come to but one conclusion, which the photographs here published corroborate—namely, that the writer has no experience of what we in France call serious fractures of the jaws due to gunshot wounds. For over two years I have given unremitting attention to facial injuries and fractured jaws, and have obtained in the majority of cases more than good results; but in citing some of these, and giving reasons for the various measures adopted, I will not attempt to formulate laws. For extended experience in this kind of work has shown that each case must be treated as one *sui generis*. The plastic side of the work is most important. Mutually interdependent are the oral and plastic work, and the surgeons responsible for each of these must work in co-operation, if good results are to be expected.

In July, 1916, I was fortunate in being joined by Captain H. Lawson Whale, and by mutual consideration we have obtained results which have at times exceeded our expectations. Doubtless some of our proceedings will seem unorthodox, but the results will bear examination, even when carried out on principles as revolutionary as the following:—

1. All remaining teeth should be preserved as far as possible; even old roots may be kept and filled, and may prove most useful in providing support for interdental splints. The secret of orthodontia lies in obtaining proper occlusion of teeth. To obtain a *point d'appui* for interdental apparatus is difficult in the English soldier's mouth, because his teeth are generally poor in quality and few in number. If the oral surgeon removes all roots and

stumps, and some teeth, he is indeed sacrificing his only asset. This does not necessarily mean that after teeth and roots have been used for purposes of support, they should not be extracted at a later date; nor does it mean that teeth directly in the line of fracture should not be removed. The view here expressed differs radically from that of those who would extract all roots, and the teeth on either side of the fracture. Discretion must, in fact, be exercised by the surgeon: no cast-iron rule can be observed, and if one permits oneself to be guided by narrow views, 'failure' will be the result in the majority of cases.

2. In extensive injuries of the face, the wound should be closed as soon as possible: if necessary, before placing the jaw in position. Dr. C. Powers, of the American Ambulance at Paris, recently remarked that if an emergency case of large facial wound were brought to him in peace-time, and he neglected or postponed the immediate approximation of the parts, he would later on be the defendant in a civil action-at-law. Why, then, delay in war surgery? The precise moment at which to close the wound cannot be laid down in hours

FIG. 94.

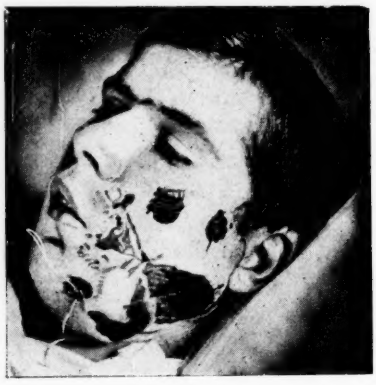


FIG. 95

or days, since of course it varies in different cases; but in general terms it may be said that, however dirty the wound, it should be closed in a few days, and long before it is thoroughly clean. In fact, an official French medical order exists, demanding that all such wounds be closed as soon as possible after having been thoroughly cleaned with ether. Perfect asepsis is in any case unattainable, since the wound is usually compound into the mouth. I have been throughout the hospitals in France, and found many faces shattered beyond any chance of satisfactory correction: large flaps hopelessly inverted, cicatrized, and almost keloidal. It should be remembered that a flap produced by laceration will quickly shrink in size, just as does one made by a surgeon in plastic work: a good reason for sewing up early.

As soon as, or even before, the palatal arch has been built up, or the jaw put into position, two rows of stitches are inserted. The deep layers, of heavy catgut, embrace fascial and muscular strata; each stitch is put in at a generous distance from the free edge, and may if desired perforate the mouth; in the latter case it is sometimes convenient to tie the knots inside

the mouth. The superficial layer, of stout salmon-gut, approximates the skin —partially in most cases, rarely completely. This layer may be reinforced by wide tension-sutures tied over vulcanite buttons (*Figs.* 94 and 95). Drainage of the mouth is generally required, and should be obtained by a median submaxillary stab-wound into which a rubber tube is inserted. It must be emphasized that these superficial stitches (other than tension stitches over buttons) are expected to break down. But while they hold, they keep the skin edges together sufficiently to allow the deeper structures to granulate—sometimes completely, sometimes leaving a buccal fistula for subsequent closure. Where there has been a loss of tissue in the upper or lower lip, however, it is unwise to draw the edges together: experience has taught me to recommend and practise the formation of an artificial hare-lip above and below, as seen in *Fig.* 116 C.

3. When, as often happens, the initial closure of soft parts precedes the orthodontal correction, there is a strong tendency for the soft parts to shrink with cicatrization. This renders the work on the jaw itself difficult or impossible, and to prevent it, interdental appliances to which wire has been attached for the grasping of modelling compound (stents) must be inserted, and increased as necessary, to preserve the contour (*Fig.* 105).

4. Under the heading (2) above, it has already been explained that the superficial stitches are expected to break down; but this should not occur too soon. To take an exaggerated instance: if the salmon-gut sutures break away a few hours after insertion, they have not had time to serve their purpose as a scaffolding, and indeed might well have been omitted. The avoidance of such happenings suggests a fourth general principle: that it is unwise to attempt to bring the parts into unnecessarily perfect position at the outset, lest the tension on the stitches should cause them to break down.

In regard to the prosthetic appliances used for the reduction of fractures of the jaw, it is difficult to lay down a law, or to express a preference for any one in particular. Cases differ so much, that the decision in each instance must always remain with the operator. I can but indicate some of the appliances I have used for certain patients herein mentioned, fully realizing that another surgeon might have treated these cases with as good results, while employing very different appliances. My endeavour has been to keep these as simple as possible, avoiding unnecessarily complicated methods.

Various ways of treating the many cases of trismus with which we come in contact have been brought forward during this war. Complicated and expensive appliances have been recommended, which in my judgement are uncalled for and unnecessary, for I have never yet had a case of false trismus which did not respond to treatment by plain wooden wedges within five or six days at the utmost; the wedges are inserted between the teeth, larger sizes being provided progressively.

The following illustrations of splints (*Figs.* 96–112) are such as I have used from time to time and have found most efficient. Some of them are original, and others I have seen in the different hospitals I have visited. If I omit to give due credit to the originator of any of these appliances, it is not from any desire to withhold it, but from ignorance of the real source.

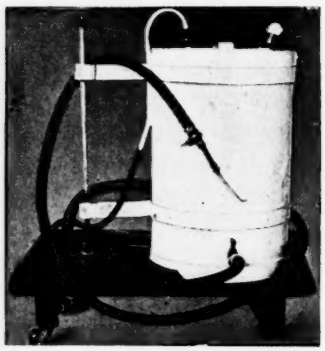


FIG. 96.

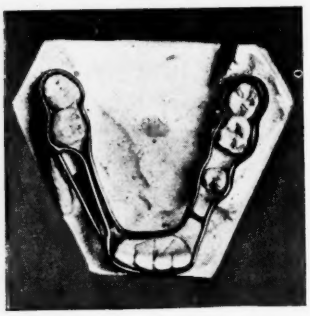


FIG. 97.

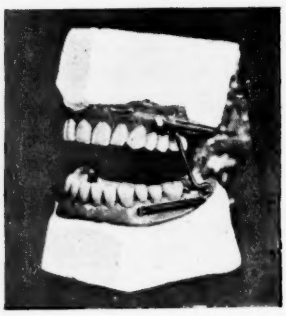


FIG. 98.

Fig. 96 shows an appliance used in my wards for cleaning wounds by means of boiled water. The patients have nicknamed it the 'Fire engine.' A petrol tin is placed upon a platform with rubber wheels, a bicycle-pump attached alongside for the purpose of obtaining pressure, and a pressure-gauge is added on the top of the tank. This is wheeled about from bed to bed by the sisters. Any solution can be used. It is simply a carrier, and saves a great deal of time.

Fig. 97.—A form of 'Hammond' splint very often used.

Fig. 98.—A simplified 'Kazanjian' spring and support made to keep up the denture when the palate has been shot away. This is a pre-war invention of Dr. Kazanjian (Harvard unit).

FIG. 99.

FIG. 100.

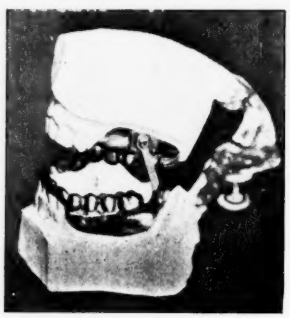


FIG. 101.

Fig. 99.—A splint used to keep the inferior maxilla in position when the fracture is posterior to the teeth.

Figs. 100 and 101.—Pope's splint, for use after loss of the condyle; I take this opportunity of recommending this ingenious apparatus.

FIG. 102.

FIG. 103.

Fig. 102.—The 'Villain' splint.

Fig. 103.—Emergency splints.

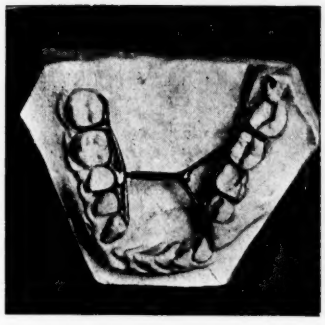


FIG. 104.

FIG. 105.

FIG. 106.

Fig. 104.—Jack-screw pushing the jaw into position.
Fig. 105.—An obturator for the superior maxilla, showing wiring vulcanized into it for the purpose of adding stents, and thus obtaining proper lines of contour for the face.

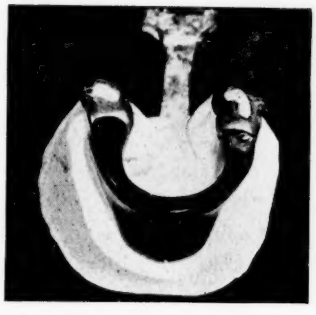


FIG. 107.

FIG. 108.

FIG. 109.

Figs. 106–8.—Show a splint for the purpose of building out the chin. This case was made for the patient in *Fig.* 109. It is constructed in four sections.

FIG. 110.

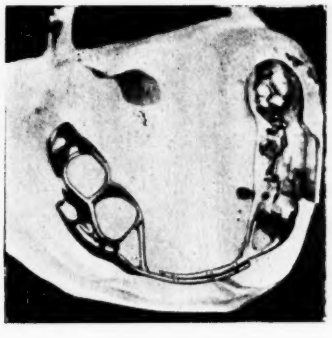


FIG. 111.

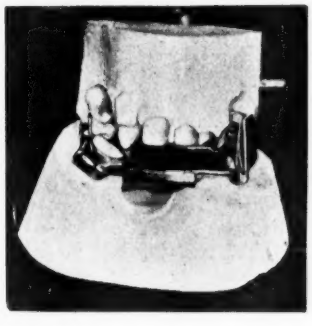


FIG. 112.

Figs. 110, 111, 112.—A flange and bridge splint, made for a patient having a fracture posterior to the right angle of the inferior maxilla : loss of bone from the second right to the second left bicuspid. The lower removable bridge maintained the line of arch in position, permitting the fracture posterior to the angle to unite. The flange held the left side of the jaw in position and removed the strain on the right side.

Some points of clinical interest to the general surgeon may be mentioned. The chief complications and sequelæ of these extensive facial injuries are the following :—

1. *Secondary Hæmorrhage.*—A slight oozing, or venous flow of one or two ounces, is fairly common. But out of 1010 cases, it has been necessary to tie an artery in its continuity through a fresh incision in only 11. The loss of tissue is often so extensive, or the track made by the projectile so deep, that it is usually impossible to acquit of responsibility for the hæmorrhage any branch of the external carotid, except the superior thyroid, posterior auricular, and occipital. Accordingly, it has become Captain Whale's routine practice, in cases of severe bleeding, to tie at once the external carotid just above the origin of the superior thyroid. The free collateral circulation, which enables the surgeon to take such liberties with the soft parts about the head and neck, also occasionally inconveniences him : thus, a unilateral wound will sometimes bleed a few days after tying the external carotid. With us, however, such hæmorrhages have never been serious enough to require further surgical interference.

2. *Tracheotomy.*—This has only been done in 2 of the 1010 cases. In one emergency it was necessary to perform laryngotomy under novocain anæsthesia (Captain Whale).

3. *Lung Complications.*—The large majority of the fractures are compound both into the mouth and outward, and only reach us two or three days after infliction, in a very fœtid state. The relative rarity of lung complications is therefore striking, and reflects great credit upon the nursing. Seven patients have died of pneumonia. The autopsies show that the lesion is generally of an inhalation type, often with massive abscess of the lung, and gangrene (Captain Greenfield). Only one rib-resection for empyema has been made (Captain Whale). For two years I have been cleaning all jaw injuries with boiled water, avoiding antiseptics as much as possible, for I believe them to be irritants, harmful to mucous surfaces.

4. *Infection of Adjacent Structures.*—There has been one case of erysipelas, and one of sinusitis (maxillary antrum, cured by operation—Captain Whale). Two patients have had quinsies, each, however, having been subject to this complaint before the war. The condition is sometimes difficult to deal with in a patient with a fractured jaw. If access to the tonsillar region is cramped by a false trismus, the wooden wedge which I use overcomes the difficulty, provided the diagnosis is so early that the quinsy can wait forty-eight hours while the wedge is doing its work.

5. *Grave Local and General Sepsis.*—One case died of streptococcal septicæmia, one of septic meningitis, and one of general pyæmia; the last had pus in his heart walls, and abscesses in most of his abdominal organs, including the jejunum and mesentery (Captain Greenfield). Two patients died of mediastinitis, which spread from a retropharyngeal abscess in the track of the missile ; in one of these, implication of the vagus and the sympathetic in the purulent track was diagnosed clinically, and confirmed post mortem (Captain Whale and Captain Greenfield).

Of 1010 cases of jaw and facial injuries, I would point out the small number of deaths (27) ; of these, 7 were beyond saving on their arrival.

The following photographs (*Figs.* 115–126) illustrate twelve cases, showing the gradual progress made from time to time. They are accompanied by clinical notes abstracted from the case records. Realizing that the photographs obtained did not clearly demonstrate the seriousness or depth of wounds, I decided on Jan. 1, 1917, to obtain them stereoscopically, and I am giving two of these here, simply for the purpose of showing their value. (*Figs.* 113, 114). They should be examined through stereoscopic lenses.

FIG. 113.

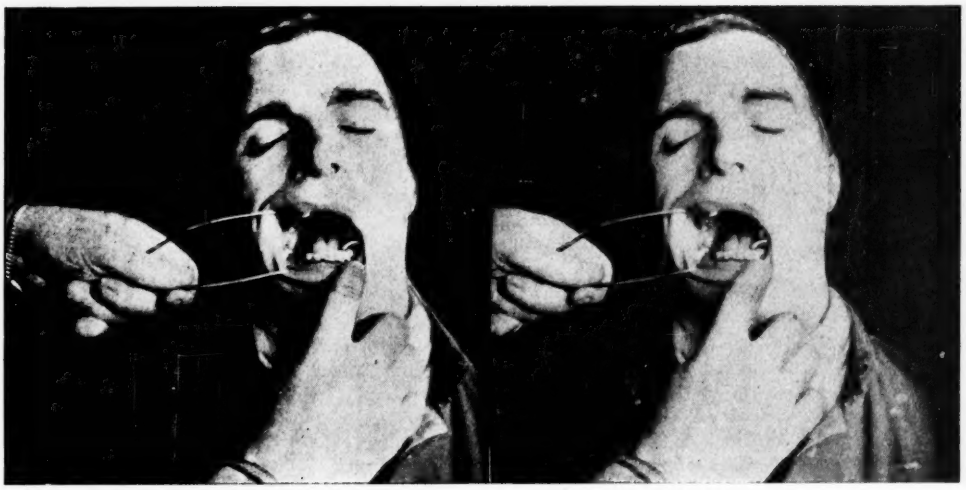
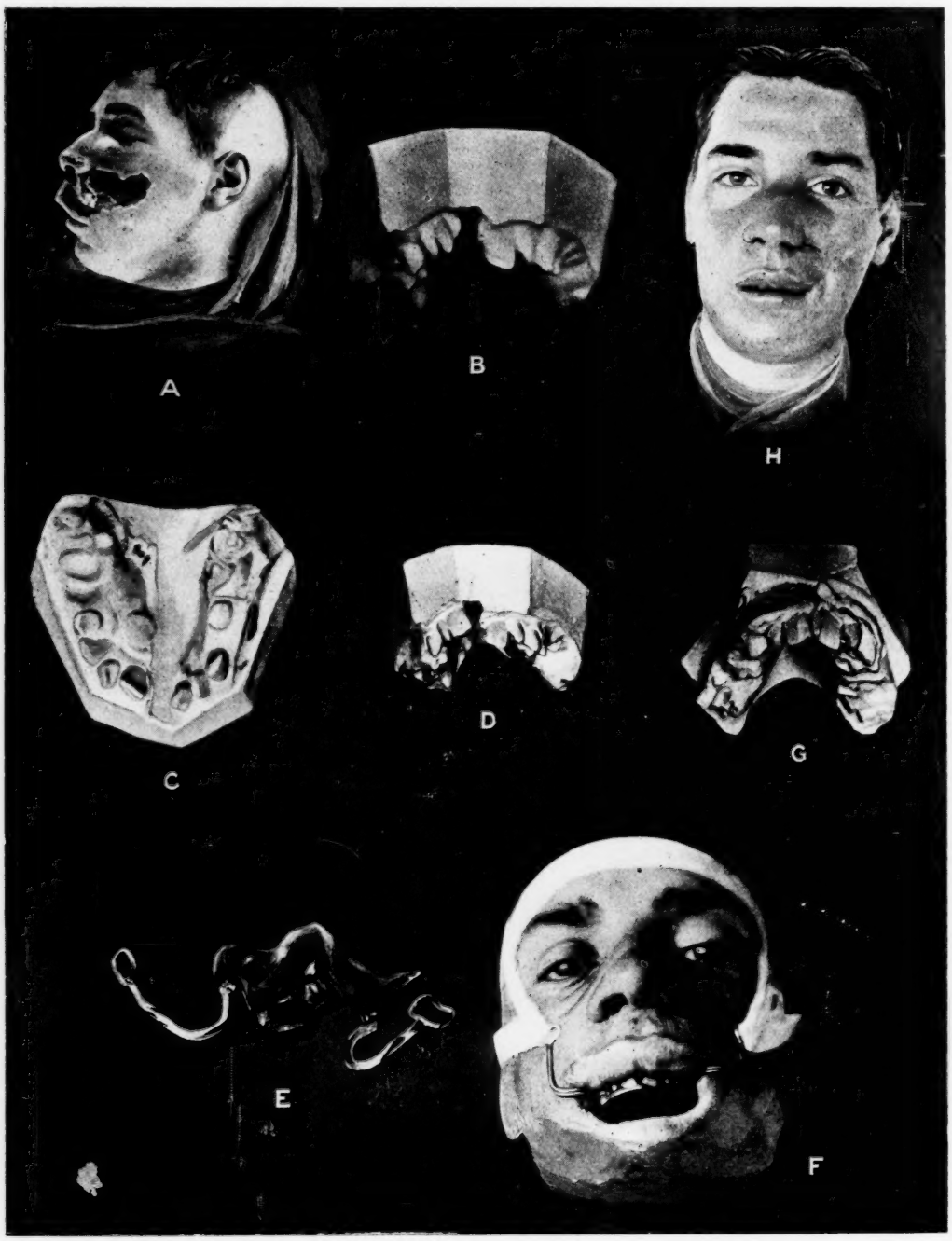


FIG. 114.

NOTES AND ILLUSTRATIONS FROM PHOTOGRAPHS OF TWELVE TYPICAL CASES.

FIG. 115.—*Case* 1. Pte. R. Gunshot wound. The projectile perforated the antrum and shattered the superior maxilla. (Major Valadier operating.)

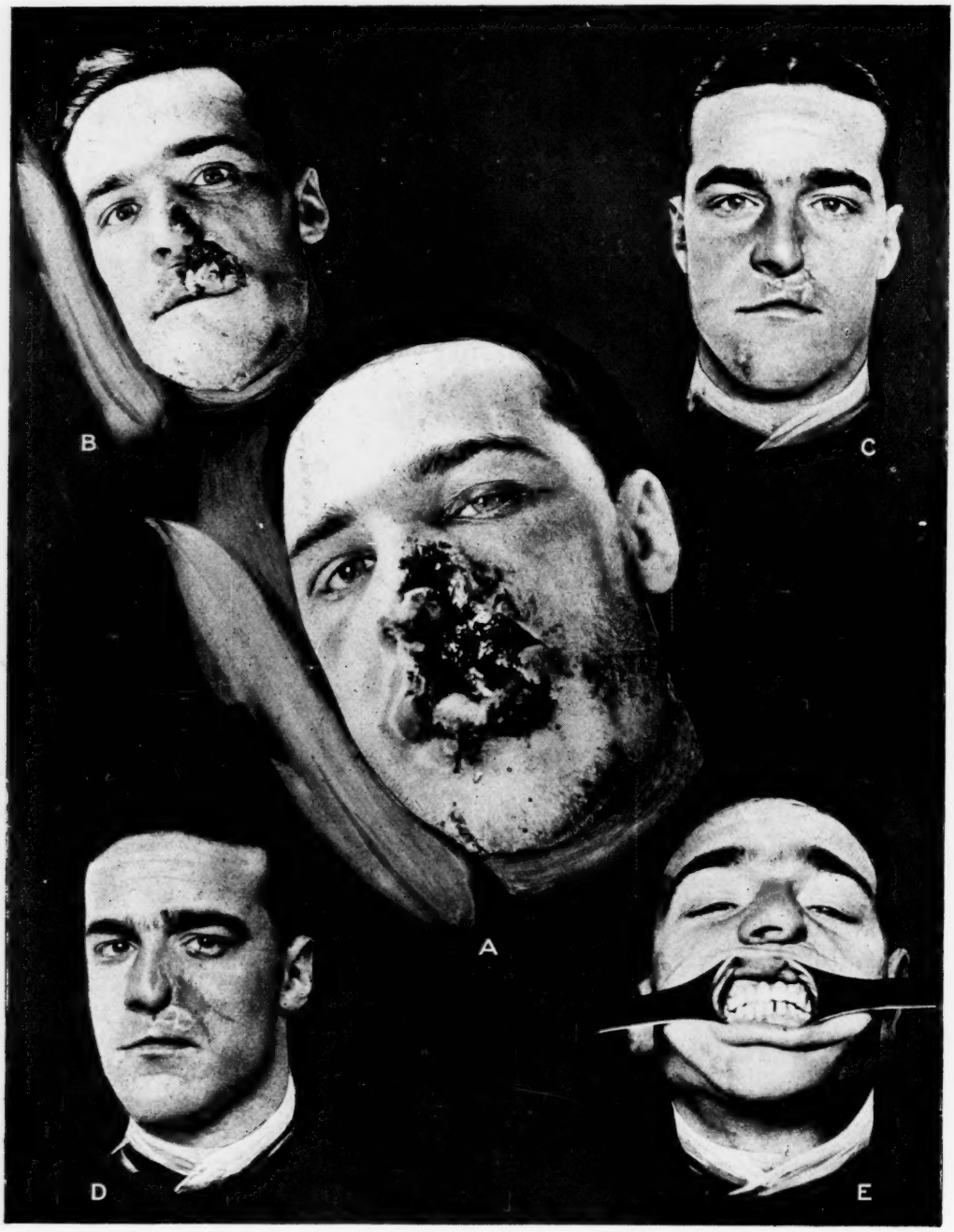


A, Patient as he arrived; B, C, D, Models of the superior maxillæ, showing the left one much below the right; E, Splint used to pull the maxilla into position; F, Splint in position; G, Maxillæ in position; H, As evacuated to England.

FIG. 116.—*Case* 2. Pte. J. S. Explosive bullet wound. The inferior maxilla was shattered; the symphysis is missing; one right and left molar, one right premolar root, and one left premolar are the only existing teeth left in the mouth. Angle bands and bar were immediately inserted to keep the line of the arch, and the wound was closed, an artificial hare-lip being formed. (Major Valadier operating six times, and Colonel Fullerton once.)

A, Patient as he arrived; B, Three weeks after arrival; C, Eight weeks after arrival. At this stage the Angle bands and bar were removed and a simple vulcanite splint was inserted, as seen in D, E. F, Hare-lip corrected. The mouth not being very straight, and considerable cicatricial tissue existing, this was re-corrected four weeks later, and then teeth were inserted: the result is seen in G and H; I, Skiagram showing present union of bone.

FIG. 117.—*Case* 3. Pte. R. W. S. Shell wound, whizz-bang. Fracture of the inferior and superior maxillæ. The superior maxilla was ligatured into position by means of silk floss, as well as the lower jaw, and the wound was immediately closed as far as possible. (Major Valadier operating; Captain Whale assisting.)



A, Patient as he arrived; B, Four weeks later; C, Upper lip corrected; D, Flap made in anticipation of forming alæ of nose; E, Present condition of the mouth after teeth were inserted.

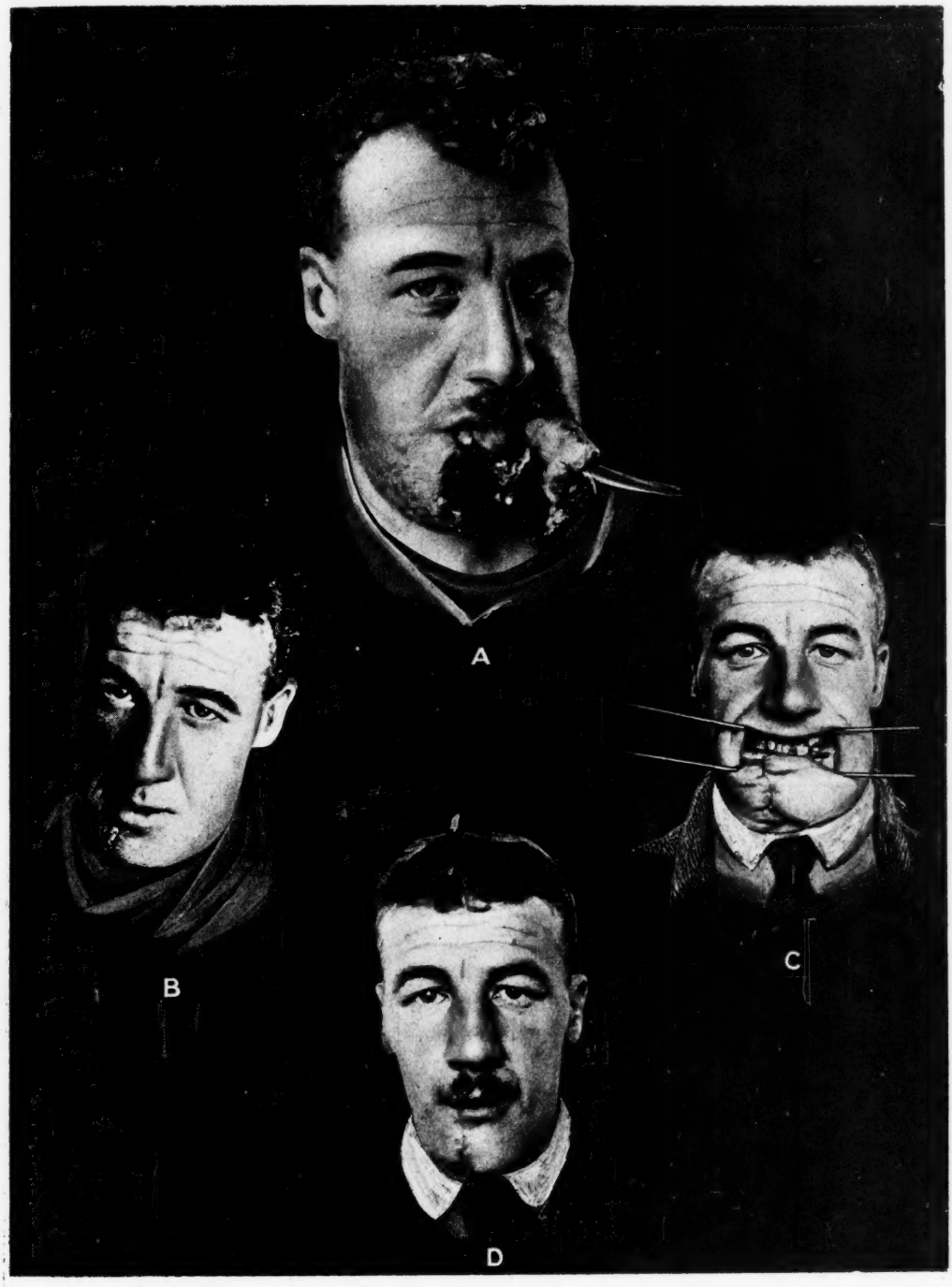
FIG. 118.—*Case* 4. Pte. S. Explosive bullet. The inferior maxilla was fractured, and an entire portion of the palate gone; both antra were open and in a most gangrenous condition. All the upper teeth were gone save one molar on each tuberosity, dangling in the mouth; both of these were ligatured into position, and in six weeks both tuberosities and teeth became absolutely sound. The wound was closed at the same time. (Major Valadier operating; Captain Whale assisting.)

A, Patient as he arrived; B, Six weeks later; C, Twelve weeks later—scar tissue removed and the cheek freed; D, Fifteen weeks later; E, Five months later (present condition); F, G, Explosive bullet removed from the maxillary sinus. It had shattered both superior maxillæ.

FIG. 119.—*Case* 5. Pte. J. P. Shell wound, high-explosive. Fracture of the inferior and superior maxillæ, with extensive facial wound. (Major Valadier operating; Captain Whale assisting.)

A, On admission; B, Ten days later. Immediate suturing: the jaws held in position by means of silk ligatures; C, Five weeks later; D, Silk ligatures removed and dentures inserted; E, F, Scar tissue removed; present appearance five months after admission.

FIG. 120.—*Case* 6. L.-Corpl. W. B. High-explosive shell wound. (Major Valadier operating ; Captain Whale assisting.)

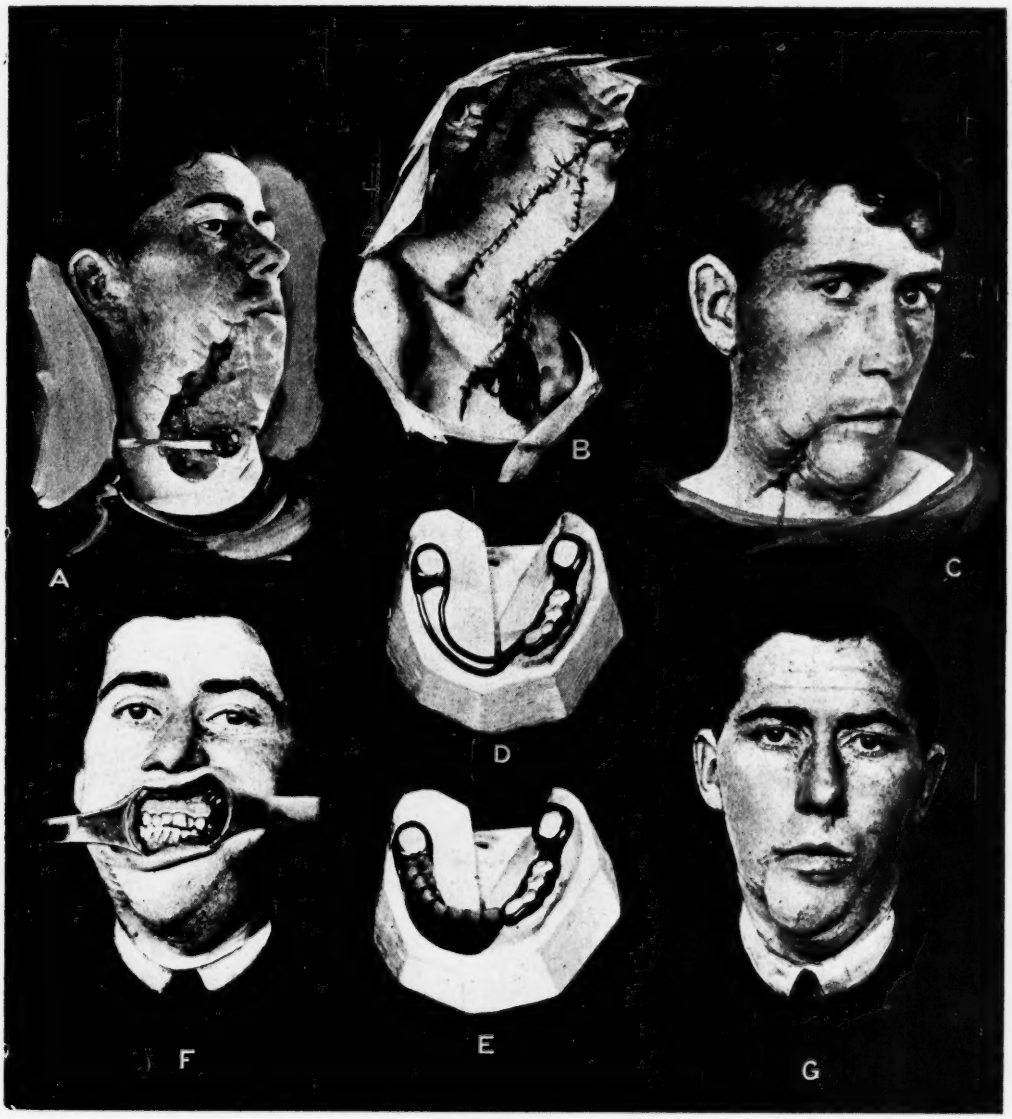


A, Patient as he arrived. The inferior maxilla was badly shattered, but healthy mucosa was found on each separate piece of bone. Therefore in this case, although I am not in favour of wiring, the bones were fixed in position by fine silver wire, and Angle bands and bar were added to preserve the line of the arch. The wound was immediately closed ; B. Three weeks after admission ; C. Shows the Angle bands and bar in position ; D, As evacuated to England, by which time the wires had been removed, with a certain amount of necrosed bone. Two centrals were also removed, as they had accomplished their purpose of support.

FIG. 121.—*Case* 7. Pte. McL. High-explosive shell wound. The superior maxilla was carried away, leaving a molar on each tuberosity; these were very loose, but it was decided to tie them into position. The inferior maxilla was fractured, right and left, posterior to the premolars. Angle bands and bar were inserted. Six weeks later, the upper teeth and tuberosity were perfectly sound. (This plan I have followed many times without a failure.) The inferior maxilla united. (Major Valadier operating.)

A, Patient as he arrived; B, Eight weeks later, with jack-screw splint to prevent contraction as seen in C; D, The splint by itself. The nose and face being depressed as seen in E, I decided to make an aluminium head-casque as in F, and a splint for the upper jaw, as seen in G, H, I; K, Shows these appliances in position; L, A side view showing the difference compared with E. At this stage, owing to pressure of work and necessity of beds for new cases, this patient was evacuated to England.

FIG. 122.—*Case* 8. Pte. P. Gunshot wound of jaw, with extensive comminution. The patient was admitted wearing a tracheotomy tube, and with a gangrenous chasm occupying the whole right anterior triangle of the neck. (Captain Whale operating; Major Valadier assisting.)



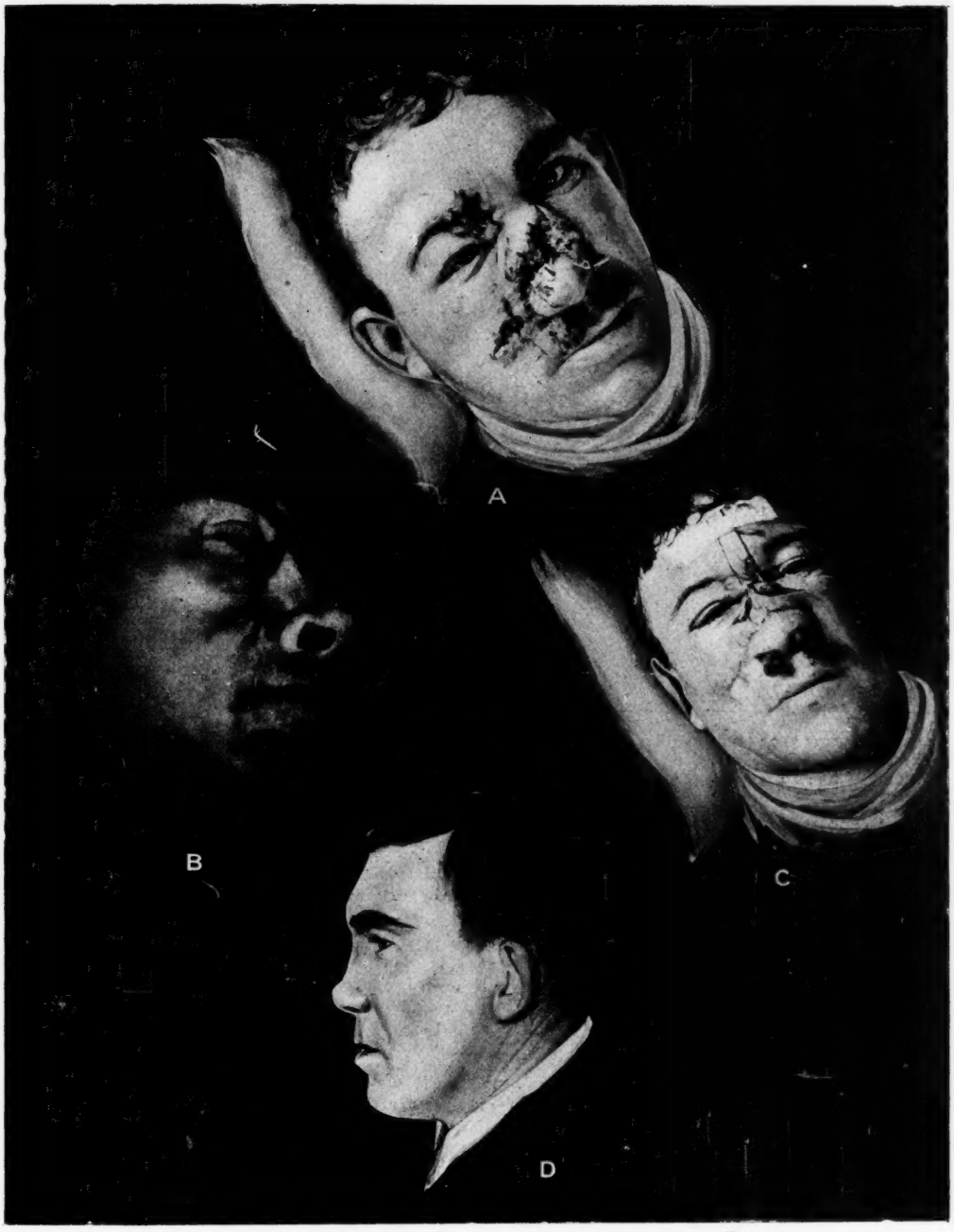
A, Appearance on admission; B, Fifteen days later. Shows a pedicled flap turned up from the chest; C, Four days later. The upper third of the flap, infected by saliva, has sloughed; D, Shows a wire trough fixed to the teeth on the sound side; E, The same with teeth to raise the level of the gap in the jaw; F, Five weeks after admission. Denture fixed; G, Present condition. The keloid scar is at present stretching.

*

FIG. 123.—*Case* 9. Pte. W. Gunshot wound, destroying the whole nose below the nasal bones. (Captain Whale operating; Major Valadier assisting.)

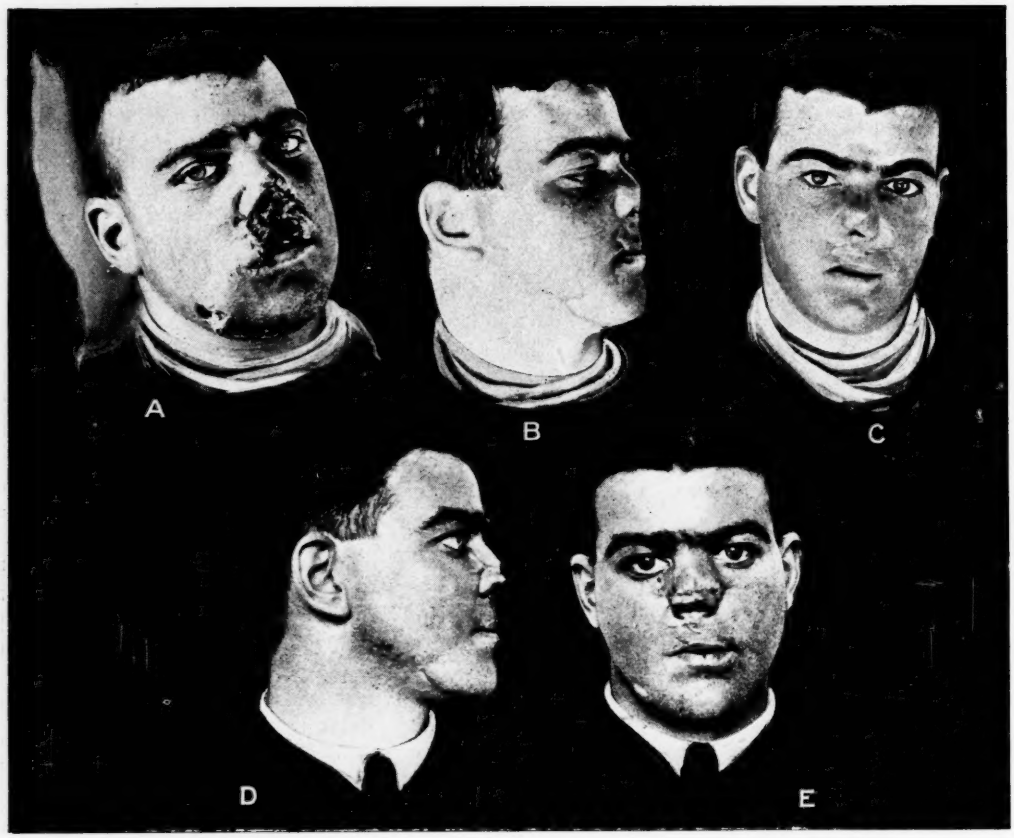
A, Appearance on admission. Vulcanite splints were made to prevent adhesions to the septum; B, Six weeks later. Piece of the 8th costal cartilage beneath the frontal periosteum; C, The same, profile view; D, Nine weeks later. Shows a frontal flap, containing cartilage, turned down; E, F, Shaping the nose.

FIG. 124.—*Case* 10. Corpl. E. Gunshot wound of the nose. The bony and soft parts between the nasal bones and the lobule were shot away. (Captain Whale operating; Major Valadier assisting.)



A, Appearance on admission. The next day the patient developed scarlet fever; B, After cicatrization eight weeks later; C, Operation three months after admission, flaps to fill the gap being taken from the skin over the nasal bones. The bridge was re-formed from the septum nasi; D, Appearance on discharge to England five months after admission.

FIG. 125.—*Case* 11. Pte. W. Gunshot wound, destroying the upper lip and premaxilla. (Captain Whale operating; Major Valadier assisting.)



A, Appearance on admission; B, C, Five weeks later. A new lip was formed, but the cicatricial tissue seen forbade re-interference to create columella and tip of nose, which I am now making from the forearm; D, E, Flaps from cheek to form the tip (not sufficient).

FIG. 126.—*Case* 12. Pte. A. Gunshot wound, destroying the right mandible, chin, and hyoid region. (Captain Whale operating; Major Valadier assisting.)

A Appearance on admission; B, Six weeks later, after a plastic operation; C, Present condition.

CAPTAIN WHALE'S REPORT.

Major Valadier has kindly asked me to add my observations to his own more important paper. He had been doing this work for eighteen months before I joined him. Up to this time my experience was limited to some patients treated jointly by Major Valadier and myself in Boulogne in the first three months of the war, before the existence of a special department, and subsequently in England to a few other cases to which I had access only after the wounds had completely healed; so that my experience of facial surgery is much less than his. I can, however, after seven months' collaboration, fully endorse the principles he has laid down, especially as regards the early closure of wounds.

At the primary operation, all tissues not hopelessly dead should be conserved. Especially does this apply to:—

1. Bone and mucous membrane. Preservation of these structures may obviate the necessity of transplantations in the case of bone, and of extensive sliding flaps in the case of mucosa, the loss of viability of either of these never being certain.

2. Parts of the face which are difficult to build up artificially, such as the columella or alar margin of the nose (see *Fig.* 124). At the beginning of the war, Major Valadier and I sacrificed pieces of tissue which we should nowadays retain. He has already mentioned that when, as is usual, the mucosa of either lip has been sewn out of its correct position to any accessible spot in order to keep it alive, it only remains thereafter to follow the general principles of hare-lip operations. We have, however, encountered one important difference. If an operation on a congenital hare-lip is for any reason unsatisfactory, the surgeon operates anew as if on a fresh case, the soft, elastic tissues, especially in an infant, permitting of this. But in our work we are dealing with inelastic and sometimes avascular cicatricial tissue, less tolerant of repeated interference. So that: (1) Provided we have obtained a good vermilion border—if the parts break down, or the cosmetic result is imperfect, it is better to let the lip heal in so far as it will, and later to perform minor operations; (2) A destroyed columella usually cannot be reconstructed by the convenient flap from the upper lip, since the wound has as a rule involved this lip also (see *Fig.* 125 B). Having restored the lip, it is unwise to disturb it again; and the columella must be made from the face by the French method, or better, from a hairless part of the arm or forearm by the Italian method.

Before finally and completely covering in a loss of skin in the region of the jaw, the buccal cavity should have been shut off, by nature's granulations, or the surgeon's stitches, or both. If this has not occurred, then, if the gap be closed by undercutting and sliding adjacent skin, a troublesome salivary fistula results. Major Valadier has been very successful in dealing with such cases by sutures of heavy catgut which embrace the deep structures only and do not reach either to the mouth or to the skin surface. But if, in order to close such a gap, it has been necessary to swing up a long pedicled flap from the thoracic wall, the evil results of an unclosed communication with the mouth are much more marked. The

distal end of the flap may slough away; and although the proximal part heals, its healing is attended by gross keloid formation, owing to the constant re-infection (see *Fig.* 122 C).

Whoever practises plastic facial work would do well not to adhere implicitly to text-book directions; thus :—

1. The time which should elapse between successive steps of surgical procedure can only be ascertained by experience. In general it may be said that the primary closure of the wound is undertaken too late, and all subsequent stages too early. In particular, the pedicles of transplanted flaps can rarely be divided safely after ten or fourteen days, as often stated; three weeks is as a rule a minimum.

2. The margin allowed for shrinkage of flaps is commonly given as one-sixth of the area. In our experience, one-third is more accurate; that is, a piece of soft tissue should be cut one-third larger than it is ultimately intended to be. It must be remembered that the flap continues to shrink for many weeks, and in all diameters. Thus, a nose made from the frontal tissues shrinks upwards towards its pedicle, so as to lie too high on the face; and the piece fashioned for the columella may shrink until it is not long enough to reach the lip (see *Fig.* 123 D).

In making a nose from a forehead flap containing a previously implanted rib cartilage, it is debatable whether the latter should be grafted superficial or deep to the periosteum. We have succeeded with both methods.

For building up smaller gaps in the nasal bridge after a subtotal loss of the nose, it is useful to swing up a vertical strip from the cut anterior edge of the cartilaginous septum; this strip remains attached to the septum at its upper end (see *Fig.* 124 C).

The later stages in the fashioning of a nose by the Indian (forehead flap) method involve reducing its thickness between the eyes, and creating the natural depression just above each ala. Such effects may be produced by excising pieces of skin in a wedge shape (Major Valadier), so that on suturing with horsehair (a mattress-suture is useful) the area is inverted. The superficial aspect of the excised piece is elliptical, and the depression produced is most marked at the widest part of the ellipse, gradually fading away towards its ends. By varying the relative length and width of the ellipse, and the slope of its edges, any sort of dimple, valley, or crease may be created.

After a wound in the region of the mandible, or at any stage of its surgical correction, an elevation or depression of one angle of the mouth is a frequent occurrence. When this is due to cicatricial contraction, there is no special point to emphasize here. But there are two other causes for such asymmetry which call for remark :—

1. Sometimes, after an extensive comminuted fracture of the lower jaw, with more or less loss of bone, it is impossible to maintain accurate apposition of the fragments by any form of splint; and these fragments, as Major Valadier first demonstrated to me, are often sufficiently viable to form callus, but will not tolerate wiring. There will be a dip in the level of the jaw on one side, dragging the angle of the mouth down with it. In such cases he devises, and his mechanicians make with a high degree

of finish, some form of bridge to raise the level of the depressed part, and on this bridge a denture is constructed. The angle of the mouth is now brought up by operation (see *Fig.* 118 C and E). It will be noticed that the mouth has eventually a false relation to the jaw on that side; but the dental occlusion is perfect, and the mouth straight. This is a better plan than to try to raise jaw and mouth together.

2. Destruction by an extensive wound of the facial nerve in the parotid region. Those who, like myself, have anastomosed the nerve with one of its neighbours, will agree that a completely successful result of this operation is rare. Here, again, it is better to lift the mouth angle by a plastic operation. The mouth in repose is then absolutely straight, and the patient's only obvious disability is a whimsically crooked smile.

SHORT NOTES OF RARE OR OBSCURE CASES.

A NOTE ON A CASE OF MYELOMA OF THE TENDON SHEATH.

By FREDERICK C. PYBUS, Newcastle-on-Tyne.

In view of the interest of these tumours, and the paper by Stewart and Flint in the British Journal of Surgery in July, 1915, I publish this case, which I saw in consultation in July, 1912.

History.—The patient, Mrs. R., age 32, was the wife of a butcher. For the previous six years she had noticed a small tumour on the little finger of the right hand. During the last year it had grown considerably larger. It was occasionally painful, and prevented her from grasping anything or putting on a glove.

Fig. 127.—Showing the under surface of the tumour, with the tendon sheath at the centre. Yellow lobules on the left-hand side, and the hand-like process at the lower and left-hand corner, are seen. (Twice natural size.)

Physical Signs.—The patient appeared generally healthy. There was present on the palmar aspect of the little finger, near its centre, an oval tumour about the size of a walnut. The skin moved over the tumour, which was lobulated and felt hard in some parts and elastic in others. The phalanges could be slightly flexed, demonstrating the freedom of the tendons. The tumour appeared to be attached to the tendon sheath.

Diagnosis.—The condition was new to me, and I could not give a definite opinion between (1) some form of ganglion, (2) neoplasm, (3) hyperplastic tubercle.

Operation.—A median incision was made over the tumour, which was found to be encapsulated and readily shelled from the surrounding tissue. It was attached by a broad base to the tendon sheath, a portion of which was removed. The sheath was closed over the tendon with catgut, and the skin edges were brought together. After removal I was still doubtful about the tumour. Drawings were made of it (*Fig.* 127), and a portion was submitted to microscopical examination.

Description of Tumour.—In size and shape it resembles a walnut.

The surface is deeply lobulated, one process resembling the fore paw of a mole. The general colour is reddish brown, while in some parts the lobules are greyish and appear translucent; in other parts they are of a yellow colour and look like wash-leather. A portion of the sheath is seen attached to the under surface of the tumour.

The late Dr. Sewell reported the specimen to be a myeloid sarcoma. The section has since been re-examined by Professor Stuart McDonald, who reports: "This appears to be a true myeloid sarcoma. The predominant cell is small and spindle-shaped, but there are numerous typical giant cells—in some fields, under the high power, from six to twelve of these are present. It is fairly vascular, and the vessels are of the usual sarcomatous type. In almost every part of the tumour there are extensive deposits of blood pigment, the result of hæmorrhage. The tumour is indistinguishable from the myeloid sarcoma arising in connection with bone."

The patient has remained quite well and free from recurrence or dissemination.

A CASE OF THROMBOSIS OF A CONSIDERABLE PORTION OF THE SUPERIOR MESENTERIC VESSELS WITHOUT ANY DISCOVERABLE CAUSE.

By OSWALD LACY ADDISON, London.

The following case seems worthy of record :—

Mrs. S., age 42, was waked up by a sudden severe pain in the abdomen at 3 a.m. on May 2, 1916. The pain continued without intermission during the day, and the abdomen became swollen. She vomited once, soon after the onset of the pain.

Patient had had no previous illness, and had gone to bed feeling perfectly well. The only possible exciting cause she could think of was that three or four days previously she had made herself very stiff and had felt 'seedy' after carrying some heavy flower-pots.

Patient, a slim, well-made woman, was admitted to the West London Hospital at 5.30 p.m. on the same day. She was pale and collapsed, with a very weak pulse of 100. The lower half of the abdomen was made prominent by a rounded, tender, elastic swelling looking like a five or six months pregnancy. The remainder of the abdomen was somewhat retracted. There was no visible peristalsis. Some dullness was present in both flanks. Examination of the pelvis was negative.

Operation at 6.30 p.m.—Condition at commencement very poor. On opening the abdomen a large quantity of blood-stained fluid escaped, and the swelling was seen to be formed by distended coils of small intestine lying transversely. The intestine was a dark plum colour, and about one and a half inches in diameter. On lifting the mass of intestines out of the abdomen there was no evidence of any kind of constriction of the mesentery, but all the vessels in the mesentery were thrombosed. The line of demarcation of the affected gut was absolutely abrupt, and ended below about three inches from

the ileocæcal valve. The gut immediately above the thrombosed part was empty and somewhat contracted. Clamps were applied, and after the removal of the affected gut with its mesentery, a lateral anastomosis was made to the colon just above the ileocæcal valve by simple suture. Owing to the collapsed condition of the patient a thorough examination of the upper half of the abdomen was not made, but the appendix and pelvic organs were seen, and appeared to be healthy. On account of the large amount of free fluid and the damaged intestine a small tube was left in for a few days, and the wound healed without infection.

Intravenous and subcutaneous saline were given during the operation, and rectal saline for two or three days after. The patient rapidly recovered from the operation, and next morning appeared to be, and said she felt, 'perfectly well.'

The temperature for the first four days did not rise above 99°, and the pulse remained 84–100. On the fifth and two subsequent nights the temperature rose to 100°, but afterwards remained subnormal. The bowels acted on the second day, and afterwards there were two or three loose motions daily.

No cause for the thrombosis was found. The patient was examined several times by Dr. Sidney Owen, but beyond a few carious teeth with no obvious pyorrhœa, a weak first sound and short apical systolic murmur, slight cardiac dilatation and weak myocardium, nothing was found. Dr. Owen did not consider that the cardiac condition was primary. The Wassermann reaction was negative. Patient left the hospital in three weeks, still rather pale, but feeling well.

Unfortunately, the piece of bowel removed was not measured at the time, and was by accident put into a strong solution of formalin. When measured four or five days later it was found to be nine feet in length. Seeing how much a piece of intestine contracts after removal, apart from the effects of immersion in strong formalin for four or five days, I think the original length cannot have been less than twelve feet, and was probably more. All the vessels of the corresponding mesentery were thrombosed, but it was not determined whether the condition was primary, or secondary to an embolism.

The most striking feature about the case was the rapidity with which the patient recovered from an apparently moribund condition—due chiefly, I think, to the fact that there was no distention of the bowel above the affected part with consequent absorption of toxins, and also to the use of spinal anæsthesia, which acted perfectly until near the end of the operation, when a very small amount of ether was given by the open method. The day after the operation the patient certainly appeared to be better than the majority of patients after a radical cure of hernia or an interval appendix operation.

The patient was seen ten months later, and seemed well, though rather pale. The weight had remained normal, and the bowels were still loose, acting as a rule twice a day. At intervals of three weeks there were attacks of griping abdominal pain followed by six or seven loose motions. She had not been able to influence the looseness of the bowels by diet. Recently she has had palpitation and some attacks of asthma, and menstruation has been irregular.

LOCALIZED TRAUMATIC OR DIRECT GANGRENE.

By Captain A. W. NUTHALL, R.A.M.C.(T.)

Private T., A.S.C., a despatch rider, fell off his motor bicycle on the stone setts of a French road. As he lay prone with his arms extended above his head, one rubber-shod wheel of a 3-ton motor lorry passed over both arms. Probably the lorry was bumping, or at least that particular wheel was not taking much weight at the moment of impact, for while the left arm sustained a severe crushing injury, the right arm escaped with mere abrasions (the man is positive that the wheel ran over both arms).

Fig. 128.

When seen on the fourth day, the left forearm presented the signs of a severe localized gangrene. There was no fracture apparent, the radial pulse was unaffected, and the condition of the forearm and hand distal to the injury quite natural. Two coloured photographs were taken which illustrate the lesion beautifully. For these I am indebted to Major A. C. Valadier. The man was in our hospital for thirty-six hours only, being transferred to England quickly in a period of great pressure. I cannot record his subsequent progress. He was seen by Colonel Burghard, at whose wish, and with the kind permission of Lieutenant-Colonel H. E. Sidgwick, the case is recorded.

A CASE OF FIBROID TUMOUR OF THE STOMACH.

By ERNEST W. HEY GROVES, Bristol.

T. C. M., age 50, a medical practitioner. There had been no previous illness until December, 1915, when, without any special warning, he had a fainting fit and passed a large quantity of blood by the rectum. In the following month he had an ordinary attack of acute pneumonia which ran

Fig. 129.—Fibroid tumour of the stomach. In the upper figure the tumour is viewed from the interior of the stomach; in the lower figure the tumour is seen in section.

a normal course. Between June and September, 1916, he had repeated attacks of melæna, but this was unassociated with dyspepsia, vomiting, or constipation. He became decidedly anæmic, and suffered from some palpitation.

Sept. 22, 1916.—Patient was well nourished and had a movable tumour in the right of the epigastrium.

Operation.—The stomach was exposed through a right pararectal incision; there were no adhesions. The organ presented a smooth soft tumour in the substance of the anterior wall. The middle third of the stomach was resected and an end-to-end anastomosis carried out without difficulty. The patient made a smooth recovery, and was able to return to his work at the end of the year. He is now in his normal health.

Description of Specimen.—The nature of the growth and its relation to the stomach are well indicated by the accompanying figures. The tumour, which was oval in shape, measured two and a half inches by one and three-quarter inches; it consisted of a soft vascular fibroid growth, exactly similar in every respect to a soft fibromyoma of the uterus. It lay in a loose connective-tissue capsule which separated it from the thickened muscular wall of the stomach on one side and from the mucous membrane on the other. The mucous membrane covering it presented two apertures, through which, no doubt, the hæmorrhage had occurred. One of these apertures was stellate and almost closed; this was probably the source of the hæmorrhage in December, 1915. The other opening was filled with recent blood-clot at the time of the operation, and it was clearly the seat of recent hæmorrhage.

At the time of the operation the tumour was regarded as probably sarcomatous, and therefore was removed with a wide margin of healthy tissue.

The occurrence of this type of fibroid tumour of the stomach is sufficiently rare to justify publication.

A CASE OF INTRAPERITONEAL PERFORATION OF AN ULCER OF THE URINARY BLADDER.

By Lieutenant-Colonel H. SIMPSON NEWLAND, A.A.M.C.,
and Captain H. RAYSON, A.A.M.C.

The interesting particulars of "A Case of Spontaneous Rupture of the Urinary Bladder," published in the October, 1916, number of The British Journal of Surgery, have led us to publish the following notes of a similar case.

Gunner H. F. J., after partaking freely of drink on the evening of Sept. 17, 1916, was knocked down by a motor car. He immediately felt severe pain in the lower part of the abdomen. At No. 3 London General Hospital a catheter was passed, and bloody urine withdrawn. On Sept. 20, four incisions were made into the anterior abdominal wall to allow the escape of extravasated urine. On Sept. 24, a suprapubic incision was made under an anæsthetic, and a rent $1\frac{1}{2}$ inches long was discovered in the anterior wall of the bladder. A large rubber drainage tube was introduced into the bladder through the tear. It was removed in the course of a few days. Six weeks later all the incisions had soundly healed.

On Feb. 2, 1917, the morning after admission to No. 1 Australian Auxiliary Hospital, he was suddenly seized with acute pain in the lower part

of the abdomen, whilst in the act of urinating. He completed the evacuation of his bladder, and with difficulty returned to the ward. On examination, he was in a state of collapse, the lips were pallid, the pulse was 130 and thready, and the temperature subnormal. The abdomen was tender all over, and did not move freely. He vomited once shortly after the onset of the pain. A slight result followed an enema, but no flatus was passed. At 2 p.m. a catheter was passed. The specimen of urine was cloudy, alkaline, and contained pus, triple phosphates, and numerous bacteria. The collapse passed off during the afternoon, the temperature rising to 100°. The pulse, however, became weaker and more rapid. The pain and tenderness tended to become localized in the left lower quadrant of the abdomen.

Operation was performed thirteen hours after the onset of the symptoms. A vertical incision was made through the left rectus, below the level of the umbilicus, and prolonged upwards later on. The omentum extended into the pelvis, and its extremity was inflamed. The pelvic coils of the small intestine were in a similar condition. The appendix being suspected, a search was made for it. The cæcum was thoroughly exposed, but no intraperitoneal appendix could be found. The cæcum was not inflamed. After a thorough search, and only after the pelvis was emptied, a tiny perforation was found low down on the peritoneal surface of the bladder. It was surrounded by pale yellow lymph. The opening was closed with catgut sutures, and a large rubber drainage tube was placed in the rectovesical fossa. The rest of the incision was closed. The patient was unable, after the operation, to retain a rubber catheter, so it was passed every six hours.

The subsequent course, except for free suppuration in the abdominal wound, has been uneventful.

This short record is entitled "A Case of Intraperitoneal Perforation of an Ulcer of the Urinary Bladder." The case recorded by Lieutenant-Colonel Sinclair White and Captain Wigram is an example of *extra*-peritoneal perforation. As these writers remark, perforation of a non-specific ulcer is a rare condition. It is interesting to remember that such a perforation may be either intra- or extraperitoneal.

REVIEWS AND NOTICES OF BOOKS.

Collected Papers of the Mayo Clinic. Edited by Mrs. M. H. MELLISH. Vol. VII, 1915. Pp. 983 + xii, with 283 illustrations. London and Philadelphia: W. B. Saunders Co.

THIS volume, comprising the papers issuing from the Clinic in 1915, follows the lines of previous publications. Many of the articles deal with questions which were well worn in earlier volumes, such as goitre and ulcers of the stomach and duodenum; beyond elaboration of operative detail in connection with ulcers of the stomach there is nothing worthy of note in the latter papers; amongst those on diseases of the thyroid, there are several interesting speculative papers on the iodine content in goitre and on blood-pressure in thyrotoxicosis.

Dr. Robinson's paper on chronic empyema reviews most of the methods adopted by others for the treatment of these very troublesome cases, and will well repay perusal by those now dealing with such conditions resulting from gunshot wounds.

Two very interesting papers on plastic surgery are those by Dr. W. Mayo on wounds of the common bile-duct, and by Dr. Charles Mayo on a most ingenious method of closing a vesico-vaginal fistula. We are pleased to see the last-named turning his master hand to the technique of operations for spina bifida, though the paper contains only brief reference to what has been the most common type in the writer's experience at a children's hospital, viz., meningo-myelocele, and there is no suggestion as to the best method of dealing with the posterior nerve-roots in these very difficult cases.

Dr. Louis Wilson contributes a practical paper on the staining of sections of living tissues, which shows that the author has personally worked at, and exercised some original thought on, this subject. Sound experimental argument is the feature of Dr. F. C. Mann's study of shock, which he endeavours to prove is coincident with and dependent upon hæmorrhage; this section of the volume alone would save it from mediocrity, and we are inclined to think that on the institution of their Department of Experimental Surgery the Mayo Clinic may chiefly base a claim for gratitude from the surgery of the future.

The wider aspects of medicine, and its value and responsibilities for the national welfare, are touched on by Dr. Wilson in the final paper, which deals with necropsies as a Public Service; we welcome such a departure from stereotyped subjects as an intimation that the best minds of Rochester have thoughts outside publications of less permanent worth if of more immediate commercial value. The illustrations, particularly that by Miss Fry in Dr. William Mayo's kidney paper, are in every way admirable, and reflect credit no less upon the surgeon who chose their subject than upon the artist who gave his thoughts expression.

Le Traitement des Plaies Infectées. Par A. CARREL et G. DEHELLY. Collection Horizon. Pp. 177, illustrated. 1917. Paris: Masson et Cie.

The Treatment of Infected Wounds. By A. CARREL and G. DEHELLY. Translation by CAPTAIN HERBERT CHILD, R.A.M.C. (temp.), with Introduction by SIR ANTHONY A. BOWLBY, K.C.M.G., K.C.V.O., F.R.C.S., Surgeon-General A.M.S. Pp. 238. 1917. London: Ballière, Tindall & Cox. 5s. net.

THIS is an excellent book, and its appearance, both in its original French and its subsequent English form, is most opportune. All the military medical world is talking of the Carrel treatment, and no inconsiderable part of it is putting it into practice—not always, it is to be feared, exactly in the form of which its illustrious author would approve. This small volume gives the most exact details of the

method, and points out all the pitfalls and how they are to be avoided, and hence it should be in the hands of every one who is called upon to treat war wounds. It forms indeed the gospel according to Carrel, and no other instructions for the treatment that we have seen can be compared to it for wealth of detail, lucidity, or, of course, accuracy. Indeed, judging by some of the instructions for carrying out the method that we have seen issued elsewhere, this book will make clear to many for the first time what Carrel's treatment really is. It is quite possible that the "tendency to modify details" to which Sir Anthony Bowlby refers in his preface to the English translation, and which he rightly deprecates, is due rather to ignorance of what Carrel regards as the essential points in the method than to any desire to 'improve' upon the work of its distinguished author. At any rate there will be no excuse for blundering in future, for the book leaves no loophole for ignorance.

The 'Carrel treatment' is perhaps the most outstanding example of what can be done to solve a clinical problem when the research is carried out in the right manner. It is a triumphant combination of bacteriological, chemical, and clinical observation and experiment, and should bring about a closer working association between the laboratory and the clinical sides of research, which have unfortunately been too much separated in the past. Many an investigator in this war has found to his chagrin that methods which appeared to work admirably in the laboratory, and which were therefore somewhat rashly recommended, broke down hopelessly when the clinical test was applied.

It is to be hoped that the success achieved in the 'Hôpital Temporaire No. 21,' which may not unjustly be regarded as an experimental hospital set aside for the purpose of investigating the treatment of wounds, will render the Army Medical Departments of the whole civilized world thoroughly alive to the importance of purely experimental research work in the field, and that a sufficient number of hospitals of this kind will be provided in future, where the stay of the patient is not subject to military exigencies, and where, therefore, important medical problems will have a better chance of being solved than is possible under the conditions of rapid and repeated evacuation to which patients are still exposed in the present war, even at the base hospitals in France.

Concerning the method itself, this is hardly the time to speak at all unreservedly. That, under favourable circumstances, it will do what is claimed for it by its author, no one who has followed the practice at Compiègne or certain other places can doubt. But whether it is going to do this in the hands of all and sundry, time alone will show. The method has encountered the usual fate of these things. First, it was ignored; then it was said to be a good thing in skilled hands, but no use for the general; now it is entering the penultimate stage—the stage, that is, in which everyone is doing it. And so we shall work on to the final stage, when it will be possible to get a true perspective and to estimate its real value. In the meanwhile this volume will lead many into the straight path, and prevent their footsteps from straying.

The book is admirably written, and has been excellently translated by Dr. Herbert Child. It is delightfully clear and easy to read in either language. Sir Anthony Bowlby furnishes the English translation with an Introduction on the value of the method, and he sounds a rather more optimistic note than a good many critics would venture upon, especially since his remarks apply only to cases at the front, and deal only with the comparatively short time during which the method has been actively employed in the British Army, i.e., since the late autumn of 1916. The real value of Carrel's method as a war treatment must stand or fall according to the results secured by military surgeons in general, and not by what it can achieve in the hands of skilled individuals. Nothing in this war has been more striking to an onlooker who has had the opportunity of seeing the practice of many men than the importance of the personal factor in the success or failure of various lines of treatment. The only unsatisfying point about the book before us is that it does not contain statistics of a large number of cases treated by the rank and file of the profession. From the nature of things this could not be expected; but the book will certainly be the means of rendering such statistics available before very long.